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THE
OBSERVATIONS OF NEWTON
CONCERNING THE
INFLECTIONS OF LIGHT;
ACCOMPANIED BY
OTHER OBSERVATIONS DIFFERING FROM HIS;
AND
APPEARING TO LEAD TO A CHANGE
OF HIS
THEORY OF LIGHT AND COLOURS.

By G. W. J.

> ITAQUE HÆC NOSTRA, UT SÆPE DIXIMUS, FELICITATIS CUJUSDAM SUNT POTIUS QUAM FACULTATIS, ET POTIUS TEMPORIS PARTUS, QUAM INGENII.
>
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TO

SIR ISAAC NEWTON,

THESE PAGES ARE INSCRIBED

BY

A DISCIPLE,

WHO, ONLY WITH THE GREATEST REVERENCE,

PRESUMES TO AMEND HIS WORKS,

WHO OWES TO THE GREAT MASTER HIMSELF

THAT POWER, WHATEVER IT MAY BE,

AND TO HIS MEMORY

THIS ACKNOWLEDGMENT.

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OBSERVATIONS

CONCERNING THE

INFLEXIONS OF THE RAYS OF LIGHT,

AND THE

COLOURS MADE THEREBY.

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GRIMALDO has informed us, that if a beam of the ſun's light be let into a dark room through a very ſmall hole, the ſhadows of things in this light will be *larger than they ought to be if the rays went on by the bodies in ſtrait lines*, and that theſe ſhadows had *three* parallel fringes, bands or ranks of coloured light adjacent to them. But *if the hole be enlarged*, the fringes *grow broad and run into one another*, ſo that they cannot be diſtinguiſhed. Theſe broad ſhadows and fringes have been reckoned by ſome to proceed from the ordinary refraction of the air, but without due examination of the matter. For the circumſtances of the phenomenon, ſo far as I have obſerved them, are as follows:

OBSERVATION I.

I made in a piece of lead a ſmall hole with a pin, whoſe breadth was the 42d part of an inch. For 21 of thoſe pins laid together took up the breadth of half an inch. Through this hole I let into my darkened chamber a beam of the ſun's light, and found that the ſhadows of hairs, thread, pins, ſtraws, and ſuch-like ſlender ſubſtances placed in this beam of light, were *conſiderably broader than they ought to be, if the rays of light paſſed on by theſe bodies in right lines.* And particularly a hair of a man's head, whoſe breadth was but the 280th part of an inch, being held in this light, at the diſtance of about twelve feet from the hole, did caſt *a ſhadow* which at the diſtance of four inches from the hair was the ſixtieth part of an inch broad, that is, above four times broader than the hair, and at the diſtance of two feet from the hair was about the eight and twentieth part of an inch broad, that is, ten times broader than the hair, and at the diſtance of ten feet was the eighth part of an inch broad, that is, thirty-five times broader.

Nor is it material whether the hair be encompaſſed with air, or with any other pellucid ſubſtance. For I wetted a poliſhed plate of glaſs, and laid the hair in the water upon the glaſs, and then laying another poliſhed plate of glaſs upon it, ſo that the water might fill up the ſpace between the glaſſes, I held them in the aforeſaid beam of light, ſo that the light might paſs through them perpendicularly, and the ſhadow of the hair was at the ſame diſtances as big as before. The ſhadows of ſcratches made in poliſhed plates of glaſs were alſo much broader than they ought to be, and the veins in poliſhed plates of glaſs did alſo caſt the like broad ſhadows. And therefore the great breadth of theſe ſhadows proceeds from ſome other cauſe than the refraction of the air.

Let the circle X [in *Fig.* 1.] repreſent the middle of the hair; ADG, BEH, CFI, three rays paſsing by one ſide of the hair at ſeveral diſtances; KNQ, LOR, MPS, three other rays paſsing by the other ſide of the hair at the like diſtances; D, E, F, and N, O, P, the places where the rays are bent in their paſſage by the hair; G, H, I, and Q, R, S, the places where the rays fall on a paper GQ; IS the breadth of the ſhadow of the hair caſt on the paper, and TI, VS, two rays paſsing to the points I and S without bending when the hair is taken away. And it is manifeſt that all the light between theſe two rays TI and VS is bent in paſsing by the hair, and *turned aſide from the ſhadow IS*, becauſe if any part of this light were not bent, it would fall on the paper within the ſhadow, and there illuminate the paper, *contrary to experience.* And becauſe when the paper is at a great diſtance from the hair, the ſhadow is broad, and therefore the rays TI and VS are at a great diſtance from one another, it follows that the hair acts upon the rays of light at a good diſtance in their paſsing by it. But the action is ſtrongeſt on the rays which paſs by at leaſt diſtances, and grows weaker and weaker accordingly as the rays paſs by at diſtances greater and greater, as is repreſented in the ſcheme: For thence it comes to paſs, that the ſhadow of the hair is much broader in proportion to the diſtance of the paper from the hair, when the paper is nearer the hair, than when it is at a great diſtance from it.

OBSERVATION α.

Having paſſed a beam of ſolar light through a very ſmall hole about the 50th part of an inch wide, into a darkened chamber, and received it on a ſcreen of white paper at various diſtances from the hole, I obſerved the condition of the beam of light, after its paſſage, to be in ſeveral particulars different from what it ought to have been, if the rays of light *had paſſed by the edge of the hole in ſtraight lines.*

The beam appeared to be divergent in all its parts, and to be more conſiderably dilated in its dimenſions, than it ought to be by the penumbral light of the ſolar diſc ; and by meaſuring its breadths at different diſtances of obſervation from the hole, I found it to be really ſo.

In Fig. α, let X be the hole of the light's paſſage, and let XA, XB, be lines drawn from each external oppoſite edge on one ſide of the ſolar diſc, to each external oppoſite edge on the contrary ſide of the hole, croſsing one another, XCD, will repreſent the beam of light after its paſſage through the hole, at all diſtances therefrom, conſiderably larger than the penumbral cone EAB.

I meaſured the breadth of the beam at the diſtance of ſeven feet from the hole, and found it to be forty-eight fiftieth parts of an inch. The diameter of a circle being to the circumference as 1 to 3, 14, nearly, the length of an arch, or of the chord of an arch of thirty minutes, the mean apparent diameter of the ſolar diſc, to a radius of ſeven feet, will be nearly $\frac{71}{100}$, or $\frac{37}{50}$ parts of an inch. Add one-fiftieth, the diameter of the hole, thereto, and deducting $\frac{38}{50}$ from $\frac{48}{50}$, $\frac{10}{50}$, or one-fifth part of an inch, will remain, being the augmentation in breadth of the beam produced by ſome other cauſe than the penumbral light of the ſun.

The divergency therefore, and increaſed dimenſions of the beam, are produced by ſome other cauſe operating at the edge of the hole, and are only to be aſcribed to the actions or attractions of the parts of the edge of the hole upon the paſsing light, by which it is bent outwards from the centre of the beam towards the edge of the hole, in the ſame manner that all the parts and particles of all other bodies are known to attract one another, and are proved under other circumſtances to act upon light alſo. Theſe effects appear, however, from other changes of condition, which may be obſerved in the beam of light, more clearly than from the increaſed breadth alone, thus eſtabliſhed by actual meaſurement.

The light of this beam was very equally diffuſed, and almoſt uniformly denſe in all its internal central parts, being alſo tolerably well defined on its external parts or edges, in a manner very different from what it ought to have been by the penumbral light alone. But the appearances were ſomewhat different, with holes of different dimenſions.

With a hole one-tenth of an inch wide, or wider, the centre of the beam was compoſed of the denſe direct light of the ſun, unchanged in its paſſage, but farther therefrom towards the borders of the beam, this light began to decreaſe in denſity, and gradually decayed more and more in the approaches nearer and nearer to the borders, becoming at laſt conſiderably diluted and evaneſcent, and rendering the edge of the beam ill-defined and indiſtinct.

With a ſmaller hole than the laſt, the central denſe light entirely diſappeared, and, with a hole yet ſmaller than this, of the dimenſions of the firſt before-mentioned hole, the external edges of the beam became more condenſed and better defined, and the whole beam of light became, as before deſcribed, of more uniform denſity in all its parts. With a hole ſmaller than any of the foregoing, about the $\frac{1}{100}$ part of an inch wide, various colours began to appear in the beam, the central parts of which became now, in their turn, more diluted than the reſt, the external parts denſer than theſe, and bordered with tinges of yellow and red light on the very edge or margin of the beam.

All theſe appearances are to be aſcribed to the ſame attractions of the edges of the holes, and of the different parts of the edges. Theſe, when the hole is large, affect only the parts of the light paſsing neareſt to them, when the hole is reduced, they attract and dilate the whole of the paſsing light; when the hole is yet more conſiderably diminiſhed, as in the firſt part of this obſervation, they act, not only each part upon the light paſsing neareſt to each, but each part alſo upon the light paſsing neareſt to each oppoſite part of the edge, condenſing by diminiſhing the attraction and diffuſion of the light on the edges of the beam, and rendering the whole more equably and uniformly divergent, and theſe at laſt, when the hole is in its moſt reduced ſtate of about $\frac{1}{100}$ part of an inch wide, by their various actions produce colours in the paſsing light in the manner and upon the principles hereafter to be explained.

In the beam of ſolar light paſſed through the ſmall hole $\frac{1}{30}$ part of an inch wide, I obſerved the ſhadows of very ſlender bodies, pins, needles, ſtraws, hairs, to be *conſiderably broader*, *as they ought to be* in this divergent light, *than the bodies themſelves*; but as each of theſe bodies exerciſes upon the light paſsing by it, the ſame attractions by which the light is bent in paſsing through the hole, I concluded that a part of the light would be in every caſe *bent*, in paſsing by, *towards the body into the ſhadow, and illuminate it and diminiſh its breadth.* In this concluſion I was confirmed by the variations of dimenſions of the ſhadows meaſured by Newton, and by the differences of proportion he obſerved to prevail in their breadths with reſpect to the diſtances of obſervation from the hole.

In Fig. β. let L, and B, denote the oppoſite edges of the hole, $B\xi\chi L$, the divergent beam of light paſſed through the hole. Let. $A\gamma$, $K\kappa$, be two rays of this beam which would paſs on from A to γ, from K to κ, but by the interpoſition of the body or hair X, they are bent to G, and Q, at the points D and N.

Join G, and D, Q, and N, and produce the lines G D, Q N, to Y, where they meet.

The dimenſions G Q, of the ſhadow are greater than the dimenſions of the body, and *greater than they ought to be in a parallel beam*, or if the rays B ξ, A α, K κ, L λ, were parallel.

But theſe dimenſions are *leſs* than they would, or *ought to be, if the rays paſſed by the body* X, *in right lines*, without being bent by it, for then they would be $\gamma\,\kappa$, not, as they are, G Q.

Alſo, the proportion of $\delta\,\varepsilon$, to its diſtance $\alpha\,\eta$ from the hole is greater than the proportion of G Q, to its diſtance from the ſame hole.

And theſe appearances are all thus produced by an attractive force acting at the edges of the hole, and the ſides of the body, upon the rays of light.

Contrary therefore to what Grimaldo and Newton ſuppoſed, that the ſhadows of things in the beam of light uſed in their experiments, were larger and *conſiderably broader than they ought to be if the rays of light paſſed on by the bodies in ſtraight or right lines*, theſe ſhadows are in fact *leſs large and leſs broad than they ought to be if the rays paſſed by the bodies in right lines.*

In the Newtonian figure, Fig. 1. the rays A D G, B E H, C F I, and K N Q, L O R, M P S, are drawn and conſidered as parallel rays, but they ought to be drawn, as they really are, divergent after paſsing through the hole.

Newton obſerves, that it is manifeſt, that all the light is bent in paſsing by the hair, and *turned aſide from the ſhadow, becauſe if any part of the light were not ſo bent it would fall within the ſhadow, and there illuminate the paper*, contrary to experience. It is manifeſt, that the light bent in paſsing by the hair is *turned aſide towards the ſhadow*, and that part of the light ſo bent *does fall within the ſhadow, and there actually illuminates the paper* and reduces the dimenſions of the ſhadow.

Newton further obſerves, that the rays paſsing at greater and greater diſtances from the hair, and being bent therefrom at angles of leſs and leſs inflection, invade and reduce the dimenſions of the ſhadow at greater and greater diſtances of obſervation. This invaſion and reduction of the ſhadow at different diſtances, are ſuppoſed to render the ſhadow of the hair broader in proportion to the diſtance of obſervation from the hair when the paper is near, than when the paper is at a greater diſtance from it; but theſe irregularities of proportion are occaſioned by the bending of the rays neareſt to the hair *towards* the ſhadow, in lines of direction which meet at a point beyond on the other ſide of the hole. Proportionate to their diſtances from this point are the dimenſions of the ſhadow, and greater are the proportions of theſe dimenſions to the diſtances of the ſhadow *from the hair*, when the diſtances are ſmall, than when they are large, for preſerving any given greater diſtance and breadth, the leſs diſtance may be ſo reduced as to vaniſh, whilſt the breadth of the leſs ſhadow will remain.

Theſe Concluſions are further confirmed by the Obſervations of Newton made at other times in other parts of his works.

" Radii autem in aëre exiſtentes, (uti
" dudum Grimaldus, luce per foramen
" in tenebroſum cubiculum admiſsâ, in-
" venit, et ipſe quoque expertus ſum)
" in tranſitu ſuo prope corporum vel
" opacorum, vel perſpicuorum angulos,
" (quales ſunt nummorum ex auro,
" argento, et ære cuſorum termini rec-
" tanguli circulares, et cultrorum, lapi-
" dum, aut fractorum vitrorum acies)
" incurvantur circum corpora *quaſi attracti*
" *in eadem*, et ex his radiis qui in tran-
" ſitu illo *propius* accedunt ad corpora in-
" curvantur magis, quaſi *magis attracti*,
" ut ipſe etiam diligenter obſervavi: et
" qui tranſeunt ad majores diſtantias
" minus incurvantur, et *ad diſtantias ad-*
" *huc majores incurvantur aliquantulum*
" *ad partes contrarias*, et tres colorum

" faſcias efformant."—*Princi. Mathem. in Scholio, fo.* 207.

" Since metals diſſolved in acids at-
" tract but a ſmall quantity of the acid,
" their attractive force can reach but to
" a ſmall diſtance from them. And as
" in Algebra, where affirmative quantities
" vaniſh and ceaſe, there negative ones
" begin; ſo in mechanics, where at-
" traction ceaſes, there a repulſive virtue
" ought to ſucceed. And that there is
" ſuch a virtue, ſeems to follow from the
" reflections and inflections of the rays of
" light. For the rays are repelled by
" bodies in both theſe caſes without the
" immediate contact of the reflecting or
" inflecting body. It ſeems alſo to fol-
" low from the emiſsion of light; the
" ray, ſo ſoon as it is ſhaken off from a
" ſhining body by the vibrating motion
" of the parts of the body, and gets
" *beyond the reach of attraction*, being
" driven away with exceeding great
" velocity."---*Newt. Optics, fo.* 370, 371.

Beſides the ſtatement of the foregoing obſervation of Newton, that all the light neareſt to the body, " *all the light between T I, and V S, is bent from* the body or *ſhadow*," he has theſe following paſſages in this ſame work.

" But light is *never* known to follow " crooked paſſages, nor *to bend into the* " *ſhadow*."---*Opticks, fo.* 337.

" The rays which paſs *very near to the* " *edges of any* body, are bent a little by " the action of the body, as we ſhewed " above; but this bending is not towards, " but *from the ſhadow*, and is performed " only in the paſſage of the ray by the " body, and at a very ſmall diſtance from " it."---*Newt. Opt. fo.* 337, 338.

All theſe obſervations, however, three of which affirm a repulſive force excluſively to exiſt, and to be exerciſed upon light by bodies, in the parts and at the diſtances neareſt to the bodies, whilſt two affirm the exiſtence of an attractive force in theſe ſame points of place, changed at other and greater diſtances into a repulſive force, are obviouſly inconſiſtent, and might fairly be ſet againſt, and deſtroy each other.

But of the principles now applied to the explanation of the phænomena of this obſervation, the obvious truth, ſimplicity, and conformity to the general principles, order, and nature of things, are ſufficient to eſtabliſh their exiſtence beyond all power of queſtion or change, an exiſtence confirmed by the general conſent of all the phænomena, as will hereafter moſt fully appear.

One remarkable circumſtance however remains to be mentioned, which will hereafter be more particularly ſtated and explained. Of a hair, in the circumſtances of the Newtonian experiment, there is, ſtrictly ſpeaking, no ſhadow obſervable, and the dark interval obſerved between the paſsing light on both ſides of the hair is properly not a ſhadow formed by the interception of the light. So little have theſe phænomena been underſtood!

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OBSERVATION II.

THE ſhadows of all bodies (metals, ſtones, glaſs, wood, horn, ice, &c.) in this light were bordered with three parallel fringes or bands of coloured light, whereof that which was contiguous to the ſhadow was broadeſt and moſt luminous, and that which was remoteſt from it was narroweſt, and ſo faint, as not eaſily to be viſible. It was difficult to diſtinguiſh the colours, unleſs when the light fell *very obliquely* upon a ſmooth paper, or ſome other ſmooth white body, ſo as to make them appear much broader than they would otherwiſe do. And then the colours were plainly viſible in this order: The firſt or innermoſt fringe was violet and deep blue next the ſhadow, and then light blue, green, and yellow in the middle, and red without. The ſecond fringe was almoſt contiguous to the firſt, and the third to the ſecond, and both were blue within, and yellow and red without, but their colours were very faint, eſpecially thoſe of the third. The colours therefore proceeded in this order from the ſhadow; violet, indigo, pale blue, green, yellow, red; blue, yellow, red; pale blue, pale yellow and red. The ſhadows made by ſcratches and bubbles in poliſhed plates of glaſs were bordered with the like fringes of coloured light. And if plates of looking-glaſs ſloped off near the edges with a diamond-cut, be held in the ſame beam of light, the light which paſſes through the parallel planes of the glaſs will be bordered with the like fringes of colours where thoſe planes meet with the diamond-cut, and by this means there will ſometimes appear four or five fringes of colours. Let AB, CD [in *Fig.* 2.] repreſent the parallel planes of a looking-glaſs, and B D the plane of the diamond-cut, making at B a very obtuſe angle with the plane A B. And let all the light between the rays E N I and F B M paſs directly through the parallel planes of the glaſs, and fall upon the paper between I and M, and all the light between the rays G O and H D be refracted by the oblique plane of the diamond-cut B D, and fall upon the paper between K and L; and the light which paſſes directly through the parallel planes of the glaſs, and falls upon the paper between I and M, will be bordered with three or more fringes at M.

So by looking on the ſun through a feather or black riband held cloſe to the eye, ſeveral rain-bows will appear; the ſhadows which the fibres or threads caſt on the *tunica retina*, being bordered with the like fringes of colours.

OBSERVATION III.

WHEN the hair was twelve feet diſtant from this hole, and its ſhadow fell obliquely upon a flat white ſcale of inches and parts of an inch placed half a foot beyond it, and alſo when the ſhadow fell perpendicularly upon the ſame ſcale placed nine feet beyond it; I meaſured the breadth of the ſhadow and fringes as accurately as I could, and found them in parts of an inch as follows.

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AT THE DISTANCE OF	HALF A FOOT.	NINE FEET.
The breadth of the ſhadow	$\frac{1}{54}$	$\frac{1}{9}$
The breadth between the middles of the brighteſt light of the innermoſt fringes on either ſide the ſhadow	$\frac{1}{38}$ or $\frac{1}{39}$	$\frac{7}{50}$
The breadth between the middles of the brighteſt light of the middlemoſt fringes on either ſide the ſhadow	$\frac{1}{23\frac{1}{2}}$	$\frac{4}{17}$
The breadth between the middles of the brighteſt light of the outmoſt fringes on either ſide the ſhadow	$\frac{1}{18}$ or $\frac{1}{18\frac{1}{2}}$	$\frac{3}{10}$
The diſtance between the middles of the brighteſt light of the firſt and ſecond fringes	$\frac{1}{120}$	$\frac{1}{21}$
The diſtance between the middles of the brighteſt light of the ſecond and third fringes	$\frac{1}{170}$	$\frac{1}{31}$
The breadth of the luminous part (*green*, *white*, yellow, and red) of the firſt fringe	$\frac{1}{170}$	$\frac{1}{32}$
The breadth of the darker ſpace between the firſt and ſecond fringes	$\frac{1}{240}$	$\frac{1}{45}$
The breadth of the luminous part of the ſecond fringe	$\frac{1}{290}$	$\frac{1}{55}$
The breadth of the darker ſpace between the ſecond and third fringes	$\frac{1}{340}$	$\frac{1}{63}$

These.

Theſe meaſures I took by letting the ſhadow of the hair, at half a foot diſtance, fall *ſo obliquely* on the ſcale, as to appear twelve times broader than when it fell perpendicularly on it at the ſame diſtance, and ſetting down in this table the twelfth part of the meaſures I then took.

OBSERVATION β.

ACROSS a beam of ſolar light admitted into a dark chamber through a ſmall hole in a thin piece of lead nearly $\frac{1}{30}$ of an inch wide, I interpoſed a hair of a man's head, and receiving the beam on a ſcreen or ſheet of white paper at a diſtance, and with an obliquity convenient for the purpoſe, I noted the following appearances.

At the termination of what may be conſidered as, and therefore may be called, a ſhadow, whoſe intenſity or darkneſs was not conſiderable, the following orders and diſtinctions of colours appeared. Firſt and neareſt to the dark or black parts of the ſhadow might be ſeen a diluted blue, changing into a breadth of white light, followed by breadths of yellow and red. To theſe ſucceeded an interval of diluted ſhade, then breadths of diluted violet, blue, diluted green, yellow, red, then green, diluted yellow, red; diluted green, red; white, diluted red; and finally white light. Theſe are the more general orders of the colours, and the colours themſelves, although a various eye may introduce various diſtinctions and various names, and extend them to innumerable varieties, and they are obſerved, taken, and ſelected under an arrangement formed for their peculiar exhibition. Of theſe orders, the three firſt were ſufficiently obvious and diſtinct; the laſt, evaneſcent and requiring accommodation of circumſtances to produce, and attention to perceive them.

Of theſe fringes and colours, the following tables will exhibit the order, ſucceſsion, and arrangement, according to the Newtonian obſervations and the preſent.

THE NEWTONIAN FRINGES & COLOURS.	THE OBSERVED FRINGES & COLOURS.
Shadow	Black
Violet	Greyiſh black
Indigo	Greyiſh blue
Pale blue	White
Green	Yellow
Yellow	Red
Red	Dark interval
Blue	Diluted violet
Yellow	Blue
Red	Diluted green
Pale blue	Yellow
Pale yellow	Red
Red.	Green
	Diluted yellow
	Red
	Diluted green
	Red
	White
	Diluted Red
	White light

In adjuſting the foregoing experiment, and ſtating therefrom the orders and ſucceſsions of colours, I have been guided and aſsiſted by comparing them with the fringes obſerved between the edges of two bodies, and hereaſter to be deſcribed, which are produced and made in the ſame manner, and upon the ſame principles, as theſe, but in denſer light. I have had in view the analogies and connections that exiſt, and to which I would lead between theſe and the orders of colours that are obſerved under other circumſtances. I have alſo accommodated by taking the point of obſervation moſt favourable to the purpoſe, and I have prepared a general ſtatement, which will generally apply to the moſt general appearances of theſe ſame orders of colours produced upon the ſame principles in different circumſtances, at or between the edges or angles of two knives, or any other adjoining bodies, between plates of glaſs, by thin plates of tranſparent ſubſtances, in the paſſage of light from luminous objects or by reflection through the pores of continuous pellucid bodies, or amidſt and by the ſides of mixed diſcontinuous bodies, as will be hereafter ſhown. With this view alſo, I have extended the ſtatement to orders more numerous than can generally be obſerved in this caſe, and which, only with the utmoſt exertion of ſenſe, guided by analogy and accommodating circumſtances to its object, can be diſtinguiſhed.

Indeed there is great room and neceſſity for this arrangement, becauſe every change of diſtance, and of obliquity of the plane of reception, exhibits varying appearances. For the above reaſons, therefore, I have thrown the violet and green out of my firſt order, and this is juſtified by the obſervations of Newton elſewhere. He has, on other occaſions, omitted the green in his firſt order, although he has retained it here; and he has here alſo retained the violet, although the violet does not elſewhere appear among his colours of the firſt order. In general, the diſtance or obliquity neceſſary to develope that green, diſperſes almoſt the violet and the blue, and this conſiderable obliquity, he expreſsly ſtates, he adapted to render the fringes broader. It did more, it changed their colours. I have not only excluded green from my firſt order of colours; I have alſo introduced the white. Although, in his ſecond obſervation, Newton makes no mention of a white, yet in the meaſurements of his third obſervation he has introduced it as a part of the firſt fringe as well as the green. The green is not always developed and apparent in the firſt fringe when the white is exhibited, and when the white only is apparent, a change of the diſtance of obſervation, or the variation of the obliquity of the plane of reception of the beam, ſhall ſometimes throw out the white and diſcover the green. For the purpoſes alſo of preſerving the general analogies and the Newtonian obſervations above referred to, I have further retained the diluted blue from the ending of the blackneſs of the ſhadow, and have by ſo doing obtained the white, and an arrangement which is abſolutely neceſſary for explaining the phœnomena that generally occur. The ſucceeding colours and orders are conſequent upon the diſpoſition of apparatus neceſſary ſo to produce theſe appearances.

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OBSERVATION IV.

WHEN the ſhadow and fringes were caſt obliquely upon a ſmooth white body, and that body was removed farther and farther from the hair, the firſt fringe began to appear and look brighter than the reſt of the light at the diſtance of leſs than a quarter of an inch from the hair, and the dark line or ſhadow between that and the ſecond fringe began to appear at a leſs diſtance from the hair than that of the third part of an inch. The ſecond fringe began to appear at a diſtance from the hair of leſs than half an inch, and the ſhadow between that and the third fringe at a diſtance leſs than an inch, and the third fringe at a diſtance leſs than three inches. At greater diſtances they became much more ſenſible, but kept very nearly the ſame proportion of their breadths and intervals which they had at their firſt appearing. For the diſtance between the middle of the firſt, and middle of the ſecond fringe, was to the diſtance between the middle of the ſecond and middle of the third fringe, as three to two, or ten to ſeven. And the laſt of theſe two diſtances was equal to the breadth of the bright light or luminous part of the firſt fringe. And this breadth was to the breadth of the bright light of the ſecond fringe as ſeven to four, and to the dark interval of the firſt and ſecond fringe as three to two, and to the like dark interval between the ſecond and third as two to one. For the breadths of the fringes ſeemed to be in the progreſsion of the numbers $1, \sqrt{\frac{1}{3}}, \sqrt{\frac{1}{5}}$, and their intervals to be in the ſame progreſsion with them; that is, the fringes and their intervals together, to be in the continual progreſsion of the numbers 1, $\sqrt{\frac{1}{2}}$, $\sqrt{\frac{1}{3}}$, $\sqrt{\frac{1}{4}}$, $\sqrt{\frac{1}{5}}$, or thereabouts. And theſe proportions held the ſame very nearly at all diſtances from the hair; the dark intervals of the fringes being as broad in proportion to the breadth of the fringes at their firſt appearance as afterwards at great diſtances from the hair, though not ſo dark and diſtinct.

OBSERVATION γ.

When the diſtance of obſervation from the hair under the circumſtances of the experiment in Obſervation β, was very ſmall, and before the firſt bright ſtreak of light began to appear, the ſhadow of the hair was diſtinct and well-defined, and of intenſe blackneſs. At a greater diſtance, this ſhadow appeared to be divided by a parallel line of light throughout its whole length, into two parts, and reſembled a double ſhadow, or the ſhadows of two hairs, but was by no means of the ſame degree of blackneſs as was the ſingle ſhadow obſerved cloſe to the hair. At ſtill greater diſtances, it increaſed in breadth and diminiſhed in blackneſs, whilſt the tranſverſe dimenſions of the dividing line of light increaſed at the ſame time, until, at a conſiderable diſtance from the hair, this intermediate band or line of light began to put on the appearance of colours on its edges, and to aſſume, on both ſides externally, caſts of yellowiſh and reddiſh light. By further increaſe of diſtance, this apparent ſhadow, theſe dark intervals became more diluted, and of nearly the ſame colour throughout, the line of light more and more diffuſed, and was at laſt extinguiſhed by the extreme diffuſion and ultimate inviſibility of the light that produced it.

Whilſt at all theſe different diſtances theſe changes proceed in the ſhadow, and in the light neareſt to the body, in the other adjoining parts of the light paſſing next in order of diſtance by the hair, conſiderable changes alſo are produced.

Cloſe to the body, the ſhadow of the hair, and the whole of the paſsing light apparently unchanged, may be obſerved. Further therefrom, that part of the light which conſtitutes the firſt fringe, begins to put on a conſiderable brightneſs, and to be ſeparated from the reſt of the light by a dark line of ſhade. Further, and further ſtill from the hair, the ſecond and third fringes begin alſo to appear, together with the firſt, in the form of white ſtreaks of light, ſeparated by dark intervals. At greater diſtances, theſe breadths of white light begin to exhibit colours at their edges, and at diſtances yet greater than theſe, or by conſiderable obliquities of reception, they are decompoſed and diſtributed into the three firſt fringes of the preceding obſervation *β*.

Adjacent to theſe three, in a ſtate of great dilution, approaching to evaneſcence, are the ſubſequent fringes of the ſame Obſervation, and adjacent to theſe laſt fringes to ſome diſtance from them the neareſt light is divided into alternate ſtreaks of white light, and ſhade, or luminous and dark intervals, which at the firſt and neareſt diſtances being under the circumſtances of this obſervation too ſmall and too little ſeparated for perception, and afterwards running into one another and mixing their colours, put on the appearance of white light, and can no longer be diſtinguiſhed therefrom, up to the point where, by increaſed diſtance, the action of the hair ceaſes altogether on the paſsing light.

The ſhadow that firſt appeared cloſe to the hair is perfectly and truly a ſhadow, being produced by the interception of the paſsing light by the hair.

This ſhadow, however, quickly ceaſes to appear, the rays of light neareſt to it on both ſides of the hair being bent into it at conſiderable angles of inflection and diſperſion, and croſsing, illuminating and extinguiſhing it. In parts where they at firſt croſs and are united, the double ſhadow and middle line of light appear,

the

the line of light being compoſed of this croſsing light, and the double ſhadow being formed by the two next dark intervals between this light and the light of the firſt fringes on each ſide. This double ſhadow therefore is not truly a ſhadow, nor the ſhadow of the hair, ſhadows being formed by the interception of light by a body, this only by the ſeparation and removal of the light.

Further on, the line of light becomes diſperſed and inviſible, and the two dark intervals uniting, form the appearance of a ſingle ſhadow, which yet, for the above reaſons, they are not. This appearance, however, has been repeatedly and conſtantly miſtaken for and meaſured as the ſhadow; and it is this which is the object of all the preceding Newtonian obſervations.

Obſerved cloſe to the hair, the paſsing light appears unchanged, becauſe the fringes and their dark intervals are not ſufficiently ſeparated to be ſeen diſtinct and apart. Further on, they appear with their dark intervals in the form of white and dark ſtreaks, their colours being not there ſufficiently diſperſed to be diſtinguiſhed ; but at greater diſtances colours begin to appear on the edges of, to invade and change the white into coloured ſtreaks of internal violets and blues, and external reds. At diſtances ſtill greater, as the general bendings of the fringes, and diſperſions of the rays vary, the nearer or internal colours of the further fringes mix with the further or external colours of the nearer fringes, reduce the number of colours in each fringe to three, and to two, and finally, by mixing all together, end in abſolute whiteneſs.

Under favourable circumſtances of exhibition, let X in Fig. γ, denote the hair, $A\alpha\beta B$, $Y\chi\omega Z$, the neareſt portions of light inflected into the ſhadow, $C\gamma\delta\varepsilon ED$, $F\zeta\vartheta H$, $I\iota\varkappa K$, the portions of light bent in paſsing into the three firſt or principal fringes, kh, will repreſent the true ſhadow of the hair taken cloſe thereto. At this diſtance, no part of the light is ſufficiently ſeparated for obſervation. At a, is formed p q, the appearance of the double ſhadow compoſed of the middle light n m, and the two dark intervals p n, m q, and at about or near b, it changes upon the extinguiſhment of the diſperſed middle light the ſemblance of a double into that of a ſingle ſhadow.

At different diſtances from the hair, as the intervals and breadths of the fringes increaſe according to the repreſentations of the Figure, they become viſible and diſtinguiſhed from one another, particularly the two firſt fringes on each ſide; and for the ſame reaſons, as the coloured portions of each fringe increaſe in breadth and are ſeparated from the reſt, they will at firſt appear on the edges, and afterwards, by further diſtribution, all over the fringes.

More light being bent into each fringe as it is nearer to the hair, and the light ſo bent being inflected into greater angles of general deviation, and particular diſperſion of the rays, the nearer fringes and their dark intervals will be broader than the more remote. Each ſeveral ray, as Cc, Dd, Eε, will be diſperſed into rays of different colours, the violet and the blue moſt inflected, as Cγ, Cf; the red leaſt, as Dd, Eε. and therefore the reds will be without, the violets and blues within. At greater diſtances of paſſage by the hair, the fringes, as Lλμ M, Nνο O, will be leſs bent and leſs diſperſed; but theſe bendings and diſperſions changing variouſly among themſelves, the internal colours, violet, and blue, as Iι, of the third fringe mix with the external reds of the ſecond, as Hϑ, and leave only three colours, green, yellow, and red, to the third fringe; in the ſame manner the colours of the fourth fringe are reduced to two, half the fifth fringe is made up of whitiſh light by the mixture of colours of all ſorts therein, and preſerves only a ruddy caſt in the other half by the prevalence of the denſer red light, and all further fringes are extinguiſhed by the mixtures of their light, or ceaſe to be produced by the action of the hair.

The breadths of the fringes and their dark intervals being according to the Newtonian meaſurement in the continual progreſsion 1, $\sqrt{\frac{1}{2}}$, $\sqrt{\frac{1}{3}}$, $\sqrt{\frac{1}{4}}$, $\sqrt{\frac{1}{5}}$, &c. the ſquares of their breadths are in the continual progreſsion 1, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, &c. and may be compared in theſe particulars with the breadths of the diameters of the coloured rings elſewhere obſerved by Newton. It is extremely probable that Newton had thoſe meaſures and rings of colours in view in taking and obſerving theſe. Suſpicions of analogies between them, ſurely muſt have ariſen in his mind. It is much therefore to be wondered at, that he did not ſucceed [as it may fairly be ſuppoſed he made the attempt] in tracing and diſcovering them, and of courſe go on to correct and to change his before-conceived principles for explaining the phænomena of light. Thoſe very principles were indeed oppoſed to theſe diſcoveries, and they perhaps repelled his efforts and reſiſted his ſucceſs. Theſe proportions, however, ſo far from obtaining generally in the breadths of theſe fringes and their intervals, can only be formed under particular circumſtances, if at all, in any. Indeed theſe breadths vary in their proportions to each other and among themſelves through all degrees of their poſsible extenſion. The dark intervals are totally extinguiſhed, and diſappear in the ſtreams or inflected light of the following Obſervation V. By a ſmall change of circumſtances, the diminution of the hole of the window, and the conſequently increaſed divergency of the light, the fringes begin to appear in ſlender lines of light, with their dark intervals of nearly equal breadths with the fringes. By other change of circumſtances, the further reduction of the hole and increaſed divergency of the light; by removal of the place of obſervation to greater diſtance from the hole, or change of obliquity of the plane of the light's reception, the neareſt fringes to the edge of the body become ſpread into, and occupy and extinguiſh the dark intervals between them. By further ſimilar changes, and under the circumſtances of the ſucceeding Obſervation VI. the fringes, in their ſtate of extreme divarication and tenuity of light, are diſperſed to conſiderable diſtances from each other, leaving their intervening dark intervals of breadths exceeding their own by all the degrees of poſsible relative extenſion. The above proportions of theſe different breadths therefore, ſo far from being permanent, and conſtant, and fixed, and given, vary through all the meaſures of change, the dark intervals ceaſing at one time entirely to exiſt, appearing and increaſing their abſolute and relative breadths, up to the very laſt ſtate of exiſtence, and the evaneſcence of the fringes upon whoſe exiſtence their own depends.

The breadths of theſe fringes depend altogether upon circumſtances. Their meaſures indeed, and diſtinctions, require too much nicety and ſteadineſs of perception to be obſerved and taken with preciſion. Although therefore, in the

Newtonian experiment, they may have poſſeſſed and preſerved the proportions aſsigned them, yet, under other circumſtances, they vary indefinitely. Theſe proportionate breadths are not therefore to be conſidered as permanent and unchangeable properties or qualities, as Newton would infer of theſe fringes, and has endeavoured to eſtabliſh of other fringes and orders of colours with their dark intervals.

OBSERVATION V.

THE ſun ſhining into my darkened chamber through a hole a quarter of an inch broad, I placed at the diſtance of two or three feet from the hole a ſheet of paſteboard, which was blacked all over on both ſides, and in the middle of it had a hole about three quarters of an inch ſquare for the light to paſs through. And behind the hole I faſtened to the paſteboard with pitch the blade of a ſharp knife, to intercept ſome part of the light which paſſed through the hole. The planes of the paſteboard and blade of the knife were parallel to one another, and perpendicular to the rays. And when they were ſo placed that *none of the ſun's light fell on the paſteboard*, but *all* of it paſſed through the hole to the knife, and there part of it fell upon the blade of the knife, and part of it paſſed by its edge; I let this part of the light which paſſed by, fall on a white paper two or three feet beyond the knife, and there ſaw *two* ſtreams of faint light ſhoot out both ways from the beam of light into the ſhadow, like the tails of comets. But becauſe the ſun's direct light by its brightneſs upon the paper obſcured theſe faint ſtreams, ſo that I could ſcarce ſee them, I made a little hole in the midſt of the paper for that light to paſs through and fall on a black cloth behind it; and then I ſaw *the two* ſtreams plainly. They were like one another, and pretty nearly equal in length, and breadth, and quantity of light. Their light at that end next the ſun's direct light was pretty ſtrong for the ſpace of about a quarter of an inch, or half an inch, and in all its progreſs from that direct light decreaſed gradually till it became inſenſible. The whole length of either of theſe ſtreams meaſured upon the paper at the diſtance of three feet from the knife was about ſix or eight inches; ſo that it ſubtended an angle at the edge of the knife of about 10 or 12, or at moſt 14 degrees. Yet ſometimes I thought I ſaw it ſhoot three or four degrees farther, but with a light ſo very faint that I could ſcarce perceive it, and *ſuſpected it might (in ſome meaſure at leaſt) ariſe from ſome other cauſe than the two ſtreams did.* For placing my eye in that light beyond the end of that ſtream which was behind the knife, and looking towards the knife, I could ſee *a line of light* upon its edge, and that not only when my eye was in the line of the ſtreams, but alſo when it was without that line either towards the point of the knife, or towards the handle. This line of light appeared *contiguous to the edge of the knife,* and was *narrower than the light of the innermoſt fringe,* and narroweſt when my eye was fartheſt from the direct light, and therefore ſeemed to paſs *between the light of that fringe and the edge of the knife,* and that which paſſed neareſt the edge to be moſt bent, though not all of it.

OBSERVATION δ.

THE circumſtances of the preceding obſervations conſtitute one particular caſe only of the inflexions of light, of which particular caſe indeed all the peculiarities are not there noticed, although they will be ſtated hereafter. The principles upon which they all depend, and by which theſe and all other fringes with their dark intervals are produced and regulated, are theſe.

The white rays of light are bent in paſsing by the ſide, edge, or angle of any thin plate or body, into lines of direction deviating from their original courſe towards the body.

The rays of light are not only ſo bent, they are alſo diſtributed or divided into different rays of different colours, in angles of diſperſion greater as the diſtances are leſs, and leſs as the diſtances are greater, in ſuch a manner, that of different colours at the ſame diſtance, the purples, blues, greens, yellows, and reds, are bent towards the body, the purples moſt, each of the others in due ſucceſſion leſs, and the reds leaſt, according to the order of their ſtatement, and of colours of the ſame ſorts at different diſtances, the nearer more than the more remote, and the more remote leſs than the nearer. So various however are the bendings of different colours at different diſtances, that in certain diſtinct portions of light, and at different diſtances of obſervation, the more remote and the nearer rays of different colours contained within each of theſe portions or diviſions of the light, become variouſly intermingled with each other, and by their various intermixtures form each of theſe diviſions into particoloured fringes, whilſt the rays of different diviſions, never mixing with thoſe of other diviſions, the intervals of the diviſions are preſerved and become the dark intervals which ſeparate the fringes.

Wherever the divergency of a beam of light is ſuch, that by inflection a nearer red is leſs bent than all the other equidiſtant or nearer adjoining coloured rays, and more bent than all the other more remote but adjacent rays, and alſo a further purple is more bent than all the other equidiſtant or more remote coloured rays, and leſs bent than all the other nearer adjoining rays; there a dark interval will be produced, on the ſide of which, neareſt to the body, the reds will appear; and on the ſide moſt remote, the purples and blues; and wherever two or more ſuch intervals are produced, they include between them a fringe or fringes of various breadths and colours, depending upon the relations between the diſperſions and bendings of the rays by the inflecting body and the original divergency of the beam, the purples and blues neareſt, the reds furtheſt from the body.

Let X in figure δ repreſent the angle or edge of any thin plate or body, let a A, b B, c C, d D, e E, repreſent parallel rays of a beam of white light bent and diſperſed variouſly, more at leſs, and leſs at greater diſtances, and let E ε, E 1, E 2, D δ, D 3, D 4, and ſo on, repreſent theſe rays thus bent and diſperſed; the rays thus bent and diſperſed will croſs and meet, and interfere and mingle with one another, and produce thereby only a white light. Now, as in figure ε, let the direction of the rays a A, b B, c C, d D, e E, be ſo changed, and become ſo divergent, that the purple B ϑ of the ray b B ſhall be leſs bent towards the edge X, than the red A α, of the adjoining ray a A, and more bent than all other equidiſtant or more remote rays, B 8, $B\beta$, C 6, C 5, $C\gamma$, and ſo on, and alſo that the red ray $A\alpha$ of the ray a A, ſhall be more bent towards X than the purple ray $B\vartheta$, and all other more remote rays, and leſs than all other equidiſtant or nearer rays, and no light can fall between thoſe two rays $B\vartheta$, and $A\alpha$, and therefore a dark interval $AB\vartheta\alpha$, will there be produced. Again, whilſt the bendings and diſperſions of the rays variouſly change further on, let the purple ray $E\eta$, and the red $D\delta$, be bent towards X, in the ſame various manner relatively to each other, and to all other rays, as the rays $B\vartheta$, and $A\alpha$, and another dark interval $DE\eta\delta$, will there be produced, and between theſe two dark intervals the fringe $BCD\delta\gamma\beta$ will be exhibited with the purples and blues on the ſide neareſt, the reds on the ſide furtheſt from the body X.

Upon the proportions and relations therefore which theſe bendings and diſperſions of the rays, and the divergency of the beam of light bear to each other, depend all the phænomena of the fringes.

All theſe inflections may be reduced to the four following caſes, which comprehend almoſt all the diverſities of appearance which different changes and conditions of things may produce at or by one ſide or edge of any ſingle thin plate or body of conſiderable breadth. By the ſides of different thin plates which approach ſo near to one another from contrary parts, as that each variouſly at the ſame time attracts and acts upon all the various intervening portions of light variouſly ſituated with reſpect to each, or by the ſides or edges of a thin plate or ſlender body of very ſmall breadth, the appearances are various. They are, however, and can be only underſtood and explained by reference to theſe.

In one caſe, and under certain circumſtances, the fringes are more numerous, their breadths leſs, the intervals of greater proportionate breadths, and the fringes and intervals diſtinguiſhable at greater diſtances of paſſage of the rays. Both the fringes and intervals alſo preſerve their exiſtence to greater diſtances of obſervation, and the colours of the fringes being ſeverally of leſs relative diſperſion, conſtitute by their general mixtures breadths of white light, or ſhow themſelves ſlowly at the borders of the fringes, and only at conſiderable diſtances of obſervation exhibit their various hues. This ſtate of the rays, the fringes, and their intervals, is exhibited in Fig. ζ.

Another ſtate of the fringes is delineated in fig. η; in which, after the exhibition of three or four of the firſt fringes, with one or two of the intervening dark intervals diſtinctly formed, the other intervals are deſtroyed by the running together of the fringes, whoſe colours variouſly mixing after the recurrence of only one or two more orders or ſucceſſions, end in perfect whiteneſs. This is the moſt ordinary ſtate of obſervation, and diſplays the moſt beautiful and vivid arrangement and mixture of colours. The colours thus exhibited, being produced by an accommodation and arrangement of circumſtances neceſſary for the occaſion, and named according to the principles, and with the views ſtated in Obſervation β, may be ſtated to be theſe: The part of the light bent into the ſhadow of the body, becomes more and more expanded and diluted in its progreſs internally towards the ſhadow, until, in conſequence of its dilution, it ceaſes to be viſible. From the place where it may firſt be perceived, in all its progreſs outwards from the ſhadow, its denſity is gradually increaſed, and its colour from black, diluted black, and bluiſh grey changed into a diluted white, until having arrived at a point of conſiderable intenſity of white light, it goes on to be changed into a yellow, ſucceeded by a red, terminating gradually in blackneſs: Then ſucceed diluted purple, blue, diluted green, yellow, red; purple, blue, green, yellow, red; green, diluted yellow, red; green, red; diluted green, red; white, diluted red; and white light.

If the beam of light be not very divergent, only the appearance of one ſhadowy ill-defined interval will be produced between the inflected light neareſt to the body and the reſt of the inflected light, and cloſe to this there will be a ſtrong illumination of white bright light by the condenſation in thoſe parts of the neareſt light bent and mixed together, but neither will the light be ſeparated into fringes, nor the colours be developed and appear. This ſtate of appearances is repreſented in Fig. θ.

If the beam of light be parallel, the only appearance will be a border of inflected light gradually increaſing from a ſtate of extreme dilution, ſcarcely perceivable, near the ſhadow, in progreſsive intenſity and brightneſs outwards, and after putting on a very conſiderable degree of brightneſs and ſtrong illumination, decaying gradually into the general appearance of other parts of the beam. Figure ι. ſhews the bendings and diſperſions of the rays under theſe circumſtances, which, by their different general intermixtures, produce only a white of various intenſities.

In all theſe various caſes, the light neareſt the body, whether conſtituting part of an innermoſt fringe, or being only the neareſt part of the broad border of white inflected light, formed by parallel rays, is in moſt caſes ſo conſiderably bent and diſperſed, that whether coloured or not, it is ſcarcely viſible; and the firſt or innermoſt fringe loſing its internal purples and blues, there appears in moſt caſes of inflection, whether of fringes or luminous border only, a greyiſh diluted white neareſt to the ſhadow, increaſing in brightneſs at greater and greater diſtances from the ſhadow, until it becomes a conſiderable breadth of white light, and goes on to continue ſo in one broad border, or ends in the yellow and red of the firſt fringe.

A beam of light was admitted into a dark chamber through a ſquare hole one-fourth of an inch wide, made in a thin piece of lead. Acroſs this beam of light, in a plane croſsing its axis at right angles, was placed the blade of a knife, ſo that its edge was parallel to one of the ſides of the hole. One part of the beam fell on the blade and was intercepted by it; and the other part paſſed on by the edge. On the ſide of the paſsing light neareſt to the edge, appeared a white border of inflected light, produced in the manner ſtated in the fourth general caſe of inflections, before mentioned in this Obſervation; and on the oppoſite ſide alſo, appeared another ſimilar border of ſimilarly inflected light. Theſe appearances were very diſtinct when received upon the border or margin of a ſheet of white paper, ſo placed that no part of the direct light ſhall fall upon the paper, but all of it paſs by. Theſe borders of inflected light are the ſtreams noticed by Newton in Obſervation V. being made in parallel rays of light, one by the edge of the knife, the other by the edge of the hole. The line of light alſo appeared with all the circumſtances deſcribed in the ſame Obſervation.

If in the edges of the hole, or of the knife, or of any other body uſed in the experiment, there be any irregularities of prominent or re-entering parts, ſtrong radiations of light ſhooting more diſtinctly and remotely into the ſhadow from theſe parts will appear. To circumſtances of this ſort may have been owing the radiations perceived by Newton deviating three or four degrees further than the reſt of the light into the ſhadow, and which he ſuſpected, though without reaſon, to ariſe from ſome other cauſe than did the ſtreams themſelves. Theſe irregularities always produce theſe effects in conſequence of their particular actions on particular portions of the paſsing light.

The appearance of the line of light at the edge of the knife, noticed by Newton

ton, is a circumſtance indeed worthy of obſervation and particular attention. This light is viſible not only in the lines of general direction of the ſtreams of paſsing light, but out of them, in every direction round about within certain limits, and appears broader or narrower, as ſeen in directions deviating leſs or more from the general courſe of the inflected light. It is therefore compoſed of rays of light iſſuing in various directions, and within various limitations from certain points, as radiants, which are differently diſtant from the edge of the knife, ſo as to exhibit the appearances obſerved. This extraordinary diſsipation and diffuſion of light diſtinct from the general inflection, though accompanying it under theſe circumſtances, depends upon the nature and general principles of exiſtence of light itſelf, principles oppoſed to all upon which the Newtonian doctrines are founded.

This light is not however to be diſtinguiſhed relatively to its diſtance from the edge of the knife, from that of the fringes formed under other circumſtances. In this caſe, indeed, there are no fringes with which it may be compared. In other caſes, the fringes are formed at different times, in different portions of the paſsing light, more or leſs remote from the body, and the inmoſt fringe always in the neareſt light. This light is taken out of all thoſe portions of light which, under other circumſtance, form the ſeveral neareſt fringes to the edge of the body, and *does not therefore paſs between the inmoſt fringe and the body*, but from thoſe very points of paſſage at which, under other circumſtances, the neareſt fringes are formed, is diffuſed in various directions out of the general body of the paſsing light.

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OBSERVATION VI.

I PLACED another knife by this, ſo that their edges might be parallel, and look towards one another, and that the beam of light might fall upon both the knives, and ſome part of it paſs between their edges. And when the diſtance of their edges was about the 400th part of an inch, the ſtream parted in the middle, and left a ſhadow between the two parts. This ſhadow was ſo black and dark that all the light which paſſed between the knives ſeemed to be bent, and turned aſide to the one hand or to the other. And as the knives ſtill approached one another the ſhadow grew broader, and the ſtreams ſhorter at their inward ends which were next the ſhadow, until upon the contact of the knives the whole light vaniſhed, leaving its place to the ſhadow.

And hence I gather that the light which is leaſt bent, and goes to the inward ends of the ſtreams, paſſes by the edges of the knives at the greateſt diſtance, and this diſtance, when the ſhadow begins to appear between the ſtreams, is about the 800th part of an inch. And the light which paſſes by the edges of the knives at diſtances ſtill leſs and leſs, is more and more bent, and goes to thoſe parts of the ſtreams which are farther and farther from the direct light; becauſe when the knives approach one another till they touch, thoſe parts of the ſtreams vaniſh laſt which are fartheſt from the direct light.

OBSERVATION VII.

IN the fifth Obſervation the fringes did not appear, but by reaſon of the breadth of the hole in the window became ſo broad as to run into one another, and by joining, to make one continued light in the beginning of the ſtreams. But in the ſixth, as the knives approached one another, a little before the ſhadow appeared between the two ſtreams, the fringes began to appear on the inner ends of the ſtreams on either ſide of the direct light; three on one ſide *made by the edge of one knife*, and three on the other ſide *made by the edge of the other knife*. They were diſtincteſt when the knives were placed at the greateſt diſtance from the hole in the window, and ſtill became more diſtinct by making the hole leſs, inſomuch that I could ſometimes ſee a faint lineament of a fourth fringe beyond the three above-mentioned. And as the knives continually approached one another, the fringes grew diſtincter and larger, until they vaniſhed. The outmoſt fringe vaniſhed firſt, and the middlemoſt next, and the innermoſt laſt. And after they were *all* vaniſhed, and the line of light which was in the middle between them was grown very broad, enlarging itſelf on both ſides *into the ſtreams of light deſcribed in the fifth Obſervation*, the above-mentioned ſhadow began to appear in the middle of this line, and divide it along the middle into two lines of light, and increaſed until the whole light vaniſhed. This enlargement of the fringes was ſo great that the rays which go to the innermoſt fringe ſeemed to be bent above twenty times more when this fringe was ready to vaniſh, than when one of the knives was taken away.

And from this and the former Obſervation compared, I gather, that the light of the firſt fringe paſſed by the edge of the knife at a diſtance greater than the 800th part of an inch, and the light of the ſecond fringe paſſed by the edge of the knife at a greater diſtance than the light of the firſt fringe did, and that of the third at a greater diſtance than that of the ſecond, and *that of the ſtreams of light deſcribed in the fifth and ſixth Obſervations* paſſed by the edges of the knives *at leſs diſtances* than that of any of the fringes.

OBSERVATION 8.

A BEAM of light admitted into a dark chamber through a hole about one-fourth part of an inch wide, fell upon the blades of two knives placed in a plane cutting the axis of the beam at right angles with their edges inwards, oppoſite, and parallel to each other; and whilſt the external parts of the beam were intercepted by the blades, the other middle part paſſed on by, and between the edges. When the edges were diſtant from each other, the central parts between them of the paſsing light remaining unchanged, there appeared only on the external parts of the paſsing beam neareſt to the edges, two luminous borders of inflected light, one belonging to each edge, and ſimilar each to the border or ſtream of light obſerved in Obſervations V, and δ, at the edge of a ſingle knife. Every thing elſe remaining unchanged, and the edges being moved towards one another, by their approach the central unchanged light became of courſe diminiſhed in breadth; and within the borders of inflected light, neareſt to each edge on both ſides, numerous ſlender ſtreaks of white light, ſeparated by dark intervals of almoſt equal breadths, began to appear. By the nearer approach of the knives, the central light was yet more diminiſhed in breadth, and the white ſtreaks became broader and larger, and put on the appearance of fringes of various colours with their dark intervals conſiderably diminiſhed indeed by the invaſion of the broader fringes. By the continued approach of the knives, the central light at laſt totally diſappeared, and the whole of the light paſsing between the edges, became diſtributed on either ſide into two complete ſets of fringes, each of them beginning at the central dividing line of diſtance between the edges of the knives.

Of theſe fringes, the orders and colours were in the ſame ſucceſsion taken outwards from this central line towards the edges, with thoſe of the fringes of Caſe the 2d, Obſervation δ, taken from the edge of the ſingle knife outwards, but taken from the edge of each of theſe knives to which they were neareſt, they were in exactly an inverted order of ſucceſsion, compared with the fringes of that obſervation made at the edge of a ſingle knife, and with a very ſmall hole.

As the knives continued to approach each other, the fringes continued to grow broader and broader, and began to ſeparate to greater diſtances from each other, and to diſappear by pairs at a time, one on each ſide, as they reſpectively arrived at the central dividing line, leaving always on both ſides an equal number of fringes with dark intervals of greater breadths between them. This number by degrees became reduced to the three pairs of principal fringes of Obſervation VII. and finally to the remains of the laſt ſingle pair, one at each edge, with a dark interval between them, ſpoken of in Obſervation VI. as two ſtreams of light with an intermediate ſhadow.

All theſe appearances are produced in this manner: They depend upon the divergency of the light, and the various bendings and diſperſions of different portions thereof. The divergency is given to the light by the edge neareſt to which it paſſes, the bendings and diſperſions by the remote edge.

When the edges are diſtant, only the divergency is ſeen of the inflected light at the borders of the beam neareſt to each edge. As by their mutual approach their various actions upon different portions of the intervening light begin to intermingle with each other, in the divergent parts of this inflected light, white ſtreaks at firſt, and afterwards fringes of coloured light with dark intervals begin to appear. When the whole of the paſsing light on either ſide of the central dividing line of diſtance between the edges is reduced to divergent light alone, and is ſufficiently approached by each oppoſite edge, coloured fringes appear over and occupy the whole of the light on both ſides. As the edges continue to approach, the fringes continue to increaſe in breadth, and as the quantity of paſsing light between the edges is thus leſſened, the number of the fringes is accordingly diminiſhed, and they diſappear by pairs, leaving only one ſingle pair remaining ſeparated to a conſiderable diſtance from each other by a dark interval of conſiderable breadth.

As the relations between the divergencies, bendings, and diſperſions of theſe laſt portions of inflected light become alſo changed, the fringes begin again to loſe their colours at their edges, and to put on the appearance of breadths or ſtreaks of white light, ſeparated by very broad dark intervals, and the two laſt remaining fringes loſe at laſt their colours altogether. Finally theſe two laſt alſo diſappear upon the contact of the edges.

Theſe two laſt remaining fringes are the ſtreams of light deſcribed by Newton in Obſervation VI. and of which he ſtates that thoſe parts vaniſh laſt which are fartheſt from the direct light. They only appear at laſt more remote from the central direction of the paſsing light, being then made in light moſt bent from this direction, becauſe then paſsing neareſt to the adjoining edge. Theſe ſtreams of light of Obſervation VI. and alſo the ſtreams of Obſervation V. are in Obſervation VII. ſtated to be diſtinct from theſe fringes, and to paſs by the edges of the knives reſpectively at leſs diſtances than any of the fringes. But the ſtreams of Obſervation VI. are the two very laſt remaining fringes themſelves; and the

ſtreams

ſtreams of Obſervation V. are compoſed of that very light in which all the fringes are formed, and of which they are compoſed.

OBSERVATION ζ.

THE hole through which the beam of light paſſed that fell on the parallel edges of the knives in the ſame plane being one-fiftieth part of an inch wide, when the edges were diſtant from each other, at each particular edge appeared the coloured fringes appertaining to each in ſuch a beam of light.

When the edges were moved towards each other, and the principal fringes of each edge approached the central dividing line of diſtance between them, the intervening light between the principal fringes became variouſly changed into a motley mixture of pearly appearance of various ruddy hues, and by degrees diminiſhed in breadth, and finally diſappeared upon the coming together of the principal fringes.

Theſe alſo, as they arrived at the ſame central line, were extinguiſhed, and diſappeared by pairs, whilſt in the interior white parts of the two inmoſt fringes neareſt to each edge on each ſide, ſtreaks or fringes at firſt of white, and afterwards of coloured light, with dark intervals between them, began to make their appearance. At laſt theſe principal fringes, either altogether diſappeared, or their remains were altogether changed into other fringes, which, appearing at firſt neareſt to each edge, occupied at laſt all the intervening light that paſſed between the edges. Of theſe latter fringes, and of their colours, the order and ſucceſsion is exactly contrary and oppoſite to thoſe of the former, taken either from the central line between the edges, or the edges themſelves. Of theſe, the principal fringes began at the central line, and were formed towards the edges. Of thoſe, the principal fringes began at the edges, and were formed towards the central line. The purples and blues of theſe were neareſt to, the reds moſt remote from, the central line. Of thoſe, the purples and blues were neareſt to, the reds moſt remote from, each of the edges to which they belonged. As the edges continued to approach each other, theſe latter fringes alſo began to diſappear by pairs, and were at laſt reduced to three, two, and one pair of fringes, ſeparated from each other by dark intervals, increaſing in breadth as the fringes diſappeared. The fringes alſo loſt their colours, and the two laſt putting on the appearance of white ſtreaks divided by a ſingle dark interval of conſiderable breadth, were finally extinguiſhed by the contact of the edges. Theſe appearances are produced in the light formed into coloured fringes, in the ſame manner as in the preceding Obſervation ε, they were produced in the borders of white light inflected by each edge towards itſelf.

When the edges of the knives are at a given diſtance of approach, if their movements towards each other be ſtopped, and the direction of the plane of reception of the fringes, or the diſtance of obſervation from the knives be variouſly changed; by changes alone of the obliquities or diſtances of the plane of reception, all theſe appearances may be produced. If the diſtance of obſervation from the knives be ſmall, the principal of the former fringes may be obſerved at each particular neareſt edge that produces them: This diſtance being increaſed, theſe fringes will appear to meet and run together and extinguiſh one another; and by further increaſe of diſtance, the latter fringes will begin to appear and increaſe in breadth and diſtinctneſs of formation and colour. If the diſtance again remain unchanged, one obliquity of the plane of reception will exhibit one ſtate, and another obliquity another ſtate of theſe appearances. Whoever contemplates the various changes of direction and colour produced in the light under all theſe circumſtances, will not much wonder that the illuſtrious Newton ſhould attribute motions to the rays reſembling the movements of eels. If at the commencement of the experiment a point or line be taken at the place of obſervation, as the place of a correſponding point, or of the line of ſhadow of one of the edges, the fringes will at one time be found remote from, on one ſide of, at another time remote from, on the other ſide of this point or line, and again upon this very point of place or line. This point or line they will from a diſtance advance to, paſs over, and move to a diſtance beyond, and when formed on this ſide thereof, the orders of the fringes will be formed in one direction; when formed on the other ſide thereof, in a contrary direction. The purples and blues will be neareſt to, the reds moſt remote, now from this point on this ſide, and now from this point on the oppoſite ſide. It muſt however be remembered, that all theſe changes are to be aſcribed to different changes of relation and condition of circumſtances and things, and not to changes of direction of the rays in their paſſage, whilſt all other things preſerve their place and ſtate unchanged.

OBSERVATION 7.

THE dimenſions of the hole being large, and the beam of paſsing light therefore conſiſting of parallel rays, if the edges of the knives be parallel to each other, although not in the ſame plane, but in different and diſtinct parallel planes, and whilſt that one of the edges which is neareſt to the hole is fixed, the other moves towards it, continuing in the ſame plane, the lines, bands, or ſtreaks of coloured light and ſhade will appear on the ſide of the edge neareſt to the hole, and by which the light firſt paſſes in its paſſage, and alſo on the ſide of the other edge, if the diſtance be not too great of the two planes in which the edges are; but if the diſtance of the planes be ſufficiently great, they will not appear on the ſide of the moving edge, for this edge can only approach a ſmall portion at a time of the light which has been coloured and ſpread by the fixed edge, and the whole of that light ſo approached is exceedingly ſpread and expanded by its cloſe approach to the fixed edge ; but the moving edge approaching the light bent into, and illuminating the ſhadow of the fixed edge, ſeparates that into portions of coloured light and ſhade, and ſo evidently ſhews that this is produced by the action of each edge when in the ſame plane upon the bent light of the other ; and as it can only approach the parts of this light gradually now that it is expanded and ſeparated to greater diſtances, and is not all cloſe together as at the time of expanſion, when the edges approach each other in the ſame plane, the portions of coloured light preſerve in the progreſs of the moving edge very nearly their ſame dimenſions of breadth, and ſo ſhew that in the foregoing caſe their expanſion and divergency were owing to the neareſt edge, and alſo even long after the moving edge having paſſed the furtheſt limit of the direct light, or the line dropped perpendicularly on the plane of the hole from the fixed edge, and produced therefrom, can receive no direct light from the hole paſsing by its own edge, it ſtill continues to colour even in its furtheſt and extreme ſtate of dilution and divarication, and to continue the evaneſcent formation of fringes in the light bent by the fixed edge into and towards its ſhadow.

OBSERVATINON 9.

In a beam of light paſſed into a dark chamber through a hole about the one-fiftieth part of an inch wide, a flat thin piece of lead of an oblong parallelogramic form was placed ſo that the axis of the beam was at right angles to the plane of one of the flat ſides, and part of the light falling thereon, the reſt paſſed by on either ſide of the two oppoſite parallel edges. Receiving the beam at a given diſtance of obſervation, when the breadth of the piece of lead, or the diſtance of the parallel ſides or edges was ſufficiently conſiderable, adjoining to each edge appeared the fringes of colours uſually obſerved under ſuch circumſtances.

By reduction of the breadth of the piece of lead, or the ſubſtitution of one more narrow but of ſimilar form, in the white inflected light of each innermoſt fringe on both ſides neareſt to the parallel edges, thin ſlender ſtreaks of white light, with dark intervals, began to make their appearance. By further reduction of the breadth of the lead, or the ſubſtitution of narrower pieces, theſe white ſtreaks became broader and more diſtinct, and approached the central dividing line of the ſhadow or diſtance between the oppoſite edges, putting on at the ſame time the appearance of fringes in an order of colour and ſucceſsion the ſame with that of the former fringes, the purples and blues being neareſt to, the reds moſt remote from the centre of the ſhadow. By further ſucceſsive reductions of the ſame, or ſubſtitutions of other narrower pieces of lead, theſe latter fringes advanced to the central line of the ſhadow where they met and diſappeared by pairs, whilſt the former fringes ſucceſsively became broader, until upon the extreme reduction of, or with a very narrow piece of lead, all the latter fringes diſappeared, leaving a dark intermediate ſhadow or interval of conſiderable dimenſions between the remaining fringes.

If, inſtead of thin flat pieces of lead, cylinders be uſed of various ſubſtances, of various dimenſions, down to the hair of the preceding Obſervation, the appearances will be the ſame.

A plane or cylinder of given dimenſions being employed, by change alone of the diſtance of obſervation, or of the obliquity of the plane of reception, ſimilar appearances may be exhibited.

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OBSERVATION VIII.

I CAUSED the edges of two knives to be ground truly ſtrait, and pricking their points into a board ſo that their edges might look towards one another, and meeting near their points contain a rectilinear angle, I faſtened their handles together with pitch to make this angle invariable. The diſtance of the edges of the knives from one another at the diſtance of four inches from the angular point, where the edges of the knives met, was the eighth part of an inch; and therefore the angle contained by the edges was about one degree 54′. The knives thus fixed together I placed in a beam of the ſun's light, let into my darkened chamber through a hole the 42d part of an inch wide, at the diſtance of ten or fifteen feet from the hole, and let the light which paſſed betwen their edges fall very obliquely upon a ſmooth white ruler at the diſtance of half an inch, or an inch from the knives, and there ſaw the fringes by the two edges of the knives run along the edges of the ſhadows of the knives in lines parallel to thoſe edges without growing ſenſibly broader, till they met in angles equal to the angle contained by the edges of the knives, and where they met and joined they ended without croſsing one another. But if the ruler was held at a much greater diſtance from the knives, the fringes where they were farther from the place of their meeting, were a little narrower, and became ſomething broader and broader as they approached nearer and nearer to one another, and after they met they croſſed one another, and then became much broader than before.

Whence I gather that the diſtances at which the fringes paſs by the knives are *not increaſed nor altered* by the approach of the knives, but the angles in which the rays are there bent *are much increaſed* by that approach; and

that

that the knife which is neareſt any ray determines which way the ray ſhall be bent, and the other knife *increaſes* the bent.

OBSERVATION ι.

UNDER the circumſtances of Obſervation ε, the edges of the two knives being inclined towards one another, ſo as to interſect each other, and contain a very ſmall angle between them, all the appearances were at one and the ſame time exhibited along both edges as the diſtances between them are diminiſhed, which were produced at different times by the gradual approach towards each other of the parallel edges in that obſervation. When the diſtance of the edges was conſiderable, each edge made ſeparately and apart from the other the fringes which a ſingle edge makes in ſuch a beam of light. At leſs diſtances ſucceſsively decreaſing of the edges from each other, each edge unbends and diſſolves the fringes formed by the oppoſite edge, beginning at the outmoſt and proceeding to the three principal fringes; each edge bends towards itſelf the light, which at the ſame diſtance from the oppoſite edge would, if that were a ſingle edge, be formed into ſome of the fringes belonging to it; each edge forms for itſelf in the light thus bent by the oppoſite edge towards itſelf fringes which become broader and diſappear together by pairs, one from each edge, until light and diſtance between the edges remain only ſufficient for the production of one fringe on each ſide; and theſe laſt remaining fringes each edge draws aſide and ſeparates from one other, until decaying upon the partial, they diſappear upon the total interception of the light.

At the extremities therefore of the edges at points moſt remote from the point of their interſection, the former fringes of each edge appear diſtinct and diſtant from each other, and run along the edges of the ſhadows of the knives in lines parallel to thoſe edges to meet each other. As that the knife which is neareſt any ray determines which way the ray ſhall be bent, and the other knife *increaſes* the bent.

OBSERVATION ι.

UNDER the circumſtances of Obſervation ε, the edges of the two knives being inclined towards one another, ſo as to interſect each other, and contain a very ſmall angle between them, all the appearances were at one and the ſame time exhibited along both edges as the diſtances between them are diminiſhed, which were produced at different times by the gradual approach towards each other of the parallel edges in that obſervation. When the diſtance of the edges was conſiderable, each edge made ſeparately and apart from the other the fringes which a ſingle edge makes in ſuch a beam of light. At leſs diſtances ſucceſsively decreaſing of the edges from each other, each edge unbends and diſſolves the fringes formed by the oppoſite edge, beginning at the outmoſt and proceeding to the three principal fringes; each edge bends towards itſelf the light, which at the ſame diſtance from the oppoſite edge would, if that were a ſingle edge, be formed into ſome of the fringes belonging to it; each edge forms for itſelf in the light thus bent by the oppoſite edge towards itſelf fringes which become broader and diſappear together by pairs, one from each edge, until light and diſtance between the edges remain only ſufficient for the production of one fringe on each ſide; and theſe laſt remaining fringes each edge draws aſide and ſeparates from one other, until decaying upon the partial, they diſappear upon the total interception of the light.

At the extremities therefore of the edges at points moſt remote from the point of their interſection, the former fringes of each edge appear diſtinct and diſtant from each other, and run along the edges of the ſhadows of the knives in lines parallel to thoſe edges to meet each other. As the three principal fringes of theſe approach to croſs one another, at points nearer the angle of concourſe of the edges, the intervening light by the commixture of the outmoſt fringes, puts on a motley pearly appearance of various ruddy hues.

At various leſs diſtances ſucceſsively taken from the ſame angle or point of concourſe, theſe principal fringes, after appearing to meet and croſs one another, ſeem to re-appear again on the other ſide oppoſite to that on which they were before ſeen, and ſeem to be thoſe very fringes themſelves, whilſt they gradually and imperceptibly, by the gradual and imperceptible diminution of diſtance between the edges, and change of their actions upon various portions of light, run into each other. But theſe latter fringes are not the ſame with the former, nor made in the ſame light with them; nor made in light paſsing at the ſame diſtances as are they from each edge that makes them; but theſe latter are made in that light which at the oppoſite edge, if the edge that makes them were away, would conſtitute the inmoſt fringe of that edge, whilſt the light, paſsing between them and the edge that makes them, is employed in the formation of fringes by the oppoſite edge. Theſe latter fringes therefore are formed in light more diſtant from the edge which forms them, than are the former which commence in the light immediately neareſt to each edge, and therefore in the different formation of theſe different fringes, the diſtances at which they paſs by the edges of the knives, *are altered and increaſed* by the approach of the knives.

In points yet nearer the angle of concourſe, as the edges are more near to each other, each edge makes its fringes in light more bent and more divergent, as paſsing nearer to the oppoſite edge, and therefore the fringes are more broad, and being alſo more removed on each ſide from each other, the increaſed nearneſs of the edges *ſeems* to increaſe the bending of the light, whilſt it only removes and changes the formation of the fringes into light that was before already more bent than that light in which the fringes had previouſly been formed. This latter light, though actually more bent than the former in which the fringes had been formed, is actually leſs bent than it was before the approach of the edge; the oppoſing and contrary action of the edge which makes the fringes in it, to the edge which bends it, not only forming thoſe fringes in it, but at the ſame time leſſening the general bent and divergency given by this latter edge. The approach therefore of the knives, at the ſame time that it alters and increaſes the diſtances at which theſe latter fringes paſs by the knives, diminiſhes the angles at which the rays are there bent, and whilſt each knife bends towards itſelf the rays neareſt to it, the other knife *diminiſhes* the bent.

OBSERVATION IX.

WHEN the rays fell very obliquely upon the ruler at the diſtance of the third part of an inch from the knives, the dark line *between the firſt and ſecond fringe* of the ſhadow of one knife, and the dark line between the firſt and ſecond fringe of the ſhadow of the other knife met with one another, at the diſtance of the fifth part of an inch from the end of the light which paſſed between the knives at the concourſe of their edges. And therefore the diſtance of the edges of the knives at the meeting of theſe dark lines was *the* 160*th* part of an inch. For as four inches to the eighth part of an inch, ſo is any length of the edges of the knives meaſured from the point of their concourſe to the diſtance of the edges of the knives at the end of that length, and ſo is the fifth part of an inch to the 160th part. So then the dark lines above-mentioned meet in the middle of the light which paſſes between the knives where they are diſtant the 160th part of an inch, and the one half of that light paſſes by the edge of one knife at a diſtance not greater than the 320th part of an inch, and falling upon the paper makes the fringes of the ſhadow of that knife, and the other half paſſes by the edge of the other knife, at a diſtance not greater than the 320th part of an inch, and falling upon the paper makes the fringes of the ſhadow of the other knife. But if the paper be held at a diſtance from the knives greater than the third part of an inch, the dark lines above-mentioned meet at a greater diſtance than the fifth part of an inch from the end of the light which paſſed between the knives at the concourſe of their edges; and therefore the light which falls upon the paper where thoſe dark lines meet, paſſes between the knives where the edges are diſtant above the 160th part of an inch.

For at another time, when the two knives were diſtant eight feet and five inches from the little hole in the window, made with a ſmall pin as above, the light which fell upon the paper where the aforeſaid dark lines met, paſſed between the knives, where the diſtance between their edges was as in the following table, when the diſtance of the paper from the knives was alſo as follows.

Diſtances of the Paper from the Knives in Inches.	*Diſtances between the edges of the Knives in milleſimal parts of an Inch.*
1½.	0'012
3⅓.	0'020
8⅕.	0'034
32.	0'057
96.	0'081
131.	0'087

And hence I gather, that the light which makes the fringes upon the paper *is not the ſame light at all diſtances* of the paper from the knives, but when the paper is held *near* the knives, the fringes are made *by light* which paſſes by the edges of the knives *at a leſs diſtance, and is more bent* than when the paper is held *at a greater diſtance* from the knives.

OBSERVATION κ.

ALL other circumſtances remaining of the experiment in Obſervation ι, if the diſtance alone from the hole of the plane of reception of the ſhadows and fringes be varied and changed, all their dimenſions and parts and the diſtances between theſe will be alſo varied and changed in conſequence of the divergency of the beam of light produced by paſsing through the ſmall hole of the experiment. The diſtance of obſervation from the hole being doubled or trebled, the dimenſions of all parts of the ſhadows and fringes, and of their diſtances will alſo be doubled or trebled, or the diſtance being in the ſame manner decreaſed, theſe alſo will be in the ſame manner diminiſhed ; and theſe augmentations or diminutions of parts will proceed very nearly with the ſame changes of the diſtance of obſervation, excepting only ſome variations from theſe exact proportions, occaſioned by deviations from the general divergency of the beam produced by the actions of the edges on the light neareſt to them, as in the caſe of the ſhadow of the hair in the foremoſt of theſe Obſervations. When therefore at any given diſtance of obſervation from the hole in the window the dark line between the firſt and ſecond fringes of the ſhadow of one knife, and the dark line between the firſt and ſecond fringes of the ſhadow of the other knife, meet with one another at the diſtance of the fifth part of an inch from the end of the light which paſſed between the knives at the concourſe of their edges, if a greater diſtance of obſervation be taken, the dark lines above-mentioned will meet at a greater diſtance than the fifth part of an inch from the end of the light which paſſed between the knives at the concourſe

courſe of their edges; and the diſtance of this point of meeting of the dark lines from the ſhadow of the edge of either knife, will be greater in the latter than the former caſe. So if half a dozen, or any other greater number of diſtances of obſervation from the hole be taken ſucceſsively greater, the diſtances of this point of meeting of the dark lines from the edge of either knife will alſo be found to be ſucceſsively greater. And this increaſe of diſtance is produced by the divergency of the beam of light, a cauſe which is known to exiſt, and which is alone ſufficient to account for it. The light therefore which makes the fringes is *the ſame light* at all diſtances of obſervation from the knives, or from the hole; and the fringes, when obſerved at diſtances nearer to the knives, or to the hole, *are not* made in light which paſſes by the edges of the knives at a leſs diſtance, and is more bent than when the diſtance is greater of obſervation from the knives, or the hole of the window.

The meaſures thus varying, and from this cauſe, of the diſtance of the point of concourſe of the dark lines between the inmoſt fringes of either edge from the end of the light paſsing between the point of concourſe of the edges, and of the diſtance of this ſame point from the ſhadow of either edge, can in no caſe be taken for the meaſures themſelves of the diſtances of the paſsing light that forms them at the places of its paſſage from the point of concourſe of the edges, or from the edges themſelves. The diſtance therefore of thoſe points of the edges of the knives between which the light paſſes and forms afterwards a point of concourſe of the dark lines of the inmoſt fringes of each edge, is, under the circumſtances of the Newtonian obſervation, leſs than the 160th part of an inch, and its half leſs than the 320th part of an inch. Allowing theſe meaſures to be duly taken, and to be true, at all greater diſtances from the angle of concourſe of the edges, all the fringes of each edge, except the two inmoſt, are made in light which paſſes by the edge of that knife at diſtances greater than the 320th part of an inch, and at leſs diſtances from the angle of concourſe, half the light paſsing by the edge of one knife at diſtances leſs than the 320th part of an inch, makes the fringes of the ſhadow of the other and oppoſite knife, and the other half paſsing by the edge of the other and oppoſite knife at the ſame diſtances, makes the fringes of the ſhadow of this knife.

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OBSERVATION X.

WHEN the fringes of the ſhadows of the knives fell perpendicularly upon a paper at a great diſtance from the knives, they were in the form of hyperbolas, and their dimenſions were as follows. Let CA, CB [in *Fig.* 3.] repreſent lines drawn upon the paper parallel to the edges of the knives, and between which all the light would fall, if it paſſed between the edges of the knives without inflection; DE a right line drawn through C making the angles ACD, BCE, equal to one another, and terminating all the light which falls upon the paper from the point where the edges of the knives meet; *eis*, *fkt*, and *glv*, three hyperbolical lines repreſenting the terminus of the ſhadow of one of the knives, the dark line between the firſt and ſecond fringes of that ſhadow, and the dark line between the ſecond and third fringes of the ſame ſhadow; *xip*, *ykq*, and *zlr*, three other hyperbolical lines repreſenting the terminus of the ſhadow of the other knife, the dark line between the firſt and ſecond fringes of that ſhadow, and the dark line between the ſecond and third fringes of the ſame ſhadow. And conceive that theſe three hyperbolas are like and equal to the former three, and croſs them in the points *i*, *k*, and *l*, and that the ſhadows of the knives are terminated and diſtinguiſhed from the firſt luminous fringes by the lines *e i s* and *x i p*, until the meeting and croſsing of the fringes, and then thoſe lines croſs the fringes in the form of dark lines, terminating the firſt luminous fringes within ſide, and *diſtinguiſhing them from another light* which begins to appear at *i*, and illuminates all the triangular ſpace *i p* D E*s* comprehended by theſe dark lines, and the right line D E. Of theſe hyperbolas one aſymptote is the line D E, and their other aſymptotes are parallel to the lines C A and C B. Let *r v* repreſent a line drawn any where upon the paper parallel to the aſymptote D E, and let this line croſs the right lines A C in *m*, and B C in *n*, and the ſix dark hyperbolical lines in *p*, *q*, *r*; *s*, *t*, *v*; and by meaſuring the diſtances *p s*, *q t*, *r v*, and thence collecting the lengths of the ordinates *n p*, *n q*, *n r*, or *m s*, *m t*, *m v*, and doing this at ſeveral diſtances of the line *r v* from the aſymptote D D, you may find as many points of theſe hyperbolas as you pleaſe, and thereby know that theſe curve lines are hyperbolas differing little from the conical hyperbola. And by meaſuring the lines C *i*, C *k*, C *l*, you may find other points of theſe curves.

For inſtance; when the knives were diſtant from the hole in the window ten feet, and the paper from the knives nine feet, and the angle contained by the edges of the knives to which the angles A C B is equal, was ſubtended by a chord which was to the radius as 1 to 32, and the diſtance of the line *r v* from the aſymptote D E was half an inch; I meaſured the lines *ps*, *q t*, *r v*, and found them 0’35, 0’65, 0’98 inches reſpectively; and by adding to their halfs the line $\frac{1}{2} mn$, (which here was the 128th part of an inch, or 0’0078 inches,) the ſums np, nq, nr, were 0’1828, 0’3328, 0’4978 inches. I meaſured alſo the diſtances of the brighteſt parts of the fringes which run between pq and st, qr and tv, and next beyond r and v, and found them 0’5, 0’8, and 1’17 inches.

OBSERVATION λ.

As the two laſt fringes neareſt the angle of concourſe of the edges of the knives begin to appear at the angle of croſsing of the two dark lines or intervals which bound them, and are more dilated and ſpread out towards theſe boundaries, the light which compoſes them, puts on an irregular triangular appearance. In this light, at the croſsing angle of theſe lines, theſe fringes are blended and united, exhibiting, at their external borders on both ſides, yellow and red colours, until at a diſtance nearer to the angle of concourſe of the edges of the knives, they begin to be ſeparated and divided by an intermediate dark interval between them, on both ſides of the vertical parts of which, diluted purple and blue hues appear compleating with the external yellow and red, and intervening white, the formation of theſe fringes. As this intermediate interval of darkneſs dilates and extends itſelf triangularly, the colours and light that compoſe theſe fringes gradually decay, and finally diſappear.

This triangular light, therefore, *is not another light, diſtinct and diſtinguiſhable from that of the laſt luminous fringes* neareſt to the angle of concourſe of the edges of the knives, but is the very light that conſtitutes and makes thoſe fringes. This light is thoſe fringes, and no other light does or can appear between them. The dark lines that bound them externally are the dark intervals that ſeparate them from the adjoining fringes on both ſides, and are not the termini of the ſhadows of the edges of the knives, for theſe termini never croſs each other. The dark triangular ſpace between theſe fringes, is that which in Obſervation ε, was noticed as appearing between the two laſt fringes upon the approach of the knives, as here by their proximity, and expanding itſelf in breadth until the laſt remaining white diluted light of the laſt fringes ceaſed to appear. Of the dark lines or intervals that ſeparate the fringes, as well the former which appear at each diſtinct edge, when the edges are remote from each other, as theſe latter which appear at each oppoſite edge, when the edges are approached to each other, the hyperboliſm may be aſcertained by, or depend upon the Newtonian meaſures, which it may not perhaps be neceſſary to repeat. The delicacy and accuracy required in making them, give too much occaſion for accommodation, and too little for confidence; and this confidence may ſomewhat be diminiſhed by the obſervation, that the dark intervals ſeparating the two laſt from the two fringes next to theſe laſt on either ſide, have been miſtaken for lines terminating the ſhadows of the edges of the knives. Independantly of all meaſures, where trifling errors againſt which ſenſe can ſcarcely guard will make important differences, the nature of theſe curves may better be conjectured by a proper judgment formed upon conſideration of the circumſtances under which they exiſt, and are produced. Can the actual paralleliſm of the former fringes, and their intervals to the ſhadows of their ſeparate edges be doubted of? and with the general divergency of the beam of light uſed in the experiment, or produced by the knives, and with the action of each edge operating on the light at right angles to the line of direction of the edge, or if changed by the action of the oppoſite edge being joined to it, changed to a direction more inclined towards the perpendicular lines drawn from the point of concourſe of the edges upon each edge, will not the dark lines between the two laſt of the latter fringes on either ſide neareſt to the angle of concourſe of the edges, interſect at laſt thoſe perpendicular lines?

OBSERVATION μ.

If, inſtead of the different parallel-ſided flat pieces of lead of Obſervation ϑ, a ſingle triangular piece, with a very ſmall vertical angle, or a very acute-angled cone of any ſolid ſubſtance be employed, all the phænomena which at different times appear at the ſides of the ſhadows of different pieces of lead, as their breadths or diſtances are increaſed or diminiſhed, will at one and the ſame time be exhibited at different diſtances from the vertex of the triangle or cone. At the greateſt diſtances from the vertex on either ſide of the body, appear the fringes which in ſuch a beam of light are always ſeen at the ſingle edge of any plane ſubſtance. At points nearer and nearer to the vertex, the inmoſt parts of the light of the inmoſt fringe on either ſide, become divided into alternate ſtreaks of ſhade and light, which become broader and broader, and put on the appearance of fringes. Of theſe latter fringes the order of ſucceſsion of colours is the ſame with that of the former fringes. Both ſets of fringes grow broader as they run along the edges of the body towards the vertex, to which, as they draw nigh, the latter fringes, begin to diſappear by pairs, their three principal fringes running into and mixing with the three principal of the former fringes, whilſt theſe increaſe in breadth, and are extended into their greateſt ſtate of dilution and divarication at the very vertex of the body which forms them.

OBSERVATION XI.

THE ſun ſhining into my darkened room through a ſmall round hole made in a plate of lead with a ſlender pin, as above; I placed at the hole a priſm to refract the light, and form on the oppoſite wall the ſpectrum of colours, deſcribed in the third Experiment of the firſt Book. And then I found that the ſhadows of all bodies held in the coloured light between the priſm and the wall, were bordered with fringes of the colour of that light in which they were held. In the full red light they were totally red without any ſenſible blue or violet, and in the deep blue light they were totally blue without any ſenſible red or yellow; and ſo in the green light they were totally green, excepting a little yellow and blue, which were mixed in the green light of the priſm. And comparing the fringes made in the ſeveral coloured lights, I found that thoſe made in the red light were largeſt, thoſe made in the violet were leaſt, and thoſe made in the green were of a middle bigneſs. For the fringes with which the ſhadow of a man's hair were bordered, being meaſured croſs the ſhadow at the diſtance of ſix inches from the hair, the diſtance between the middle and moſt luminous part of the firſt or innermoſt fringe on one ſide of the ſhadow, and that of the like fringe on the other ſide of the ſhadow, was in the full red light $\frac{1}{37\frac{1}{2}}$ of an inch, and in the full violet $\frac{1}{46}$. And the like diſtance between the middle and moſt luminous parts of the ſecond fringes on either ſide the ſhadow was in the full red light $\frac{1}{22}$, and in the violet $\frac{1}{27}$ of an inch. And theſe diſtances of the fringes held the ſame proportion at all diſtances from the hair without any ſenſible variation.

So then the rays which made theſe fringes in the red light paſſed by the hair at a greater diſtance than thoſe did which made the like fringes in the violet; and therefore the hair in cauſing theſe fringes acted alike upon the red light or leaſt refrangible rays at a greater diſtance, and upon the violet or moſt refrangible rays at a leſs diſtance, and by thoſe actions diſpoſed the red light into larger fringes, and the violet into ſmaller, and the lights of intermediate colours into fringes of intermediate bigneſſes without changing the colour of any ſort of light.

When therefore the hair in the firſt and ſecond of theſe Obſervations was held in the white beam of the ſun's light, and caſt a ſhadow which was bordered with three fringes of coloured light, thoſe colours aroſe not from *any new modifications impreſſed upon the rays of light by the hair*, but only from the various inflections whereby *the ſeveral ſorts of rays were ſeparated from one another*, which before ſeparation, by the mixture of all their colours, compoſed the white beam of the ſun's light, but whenever ſeparated, compoſe lights of the ſeveral colours which they are originally diſpoſed to exhibit. In this 11th Obſervation, where the colours are ſeparated before the light paſſes by the hair, the leaſt refrangible rays, which when ſeparated from the reſt make red, were inflected at a greater diſtance from the hair, ſo as to make three red fringes at a greater diſtance from the middle of the ſhadow of the hair; and the moſt refrangible rays which when ſeparated make violet, were inflected at a leſs diſtance from the hair, ſo as to make three violet fringes at a leſs diſtance from the middle of the ſhadow of the hair. And other rays of intermediate degrees of refrangibility were inflected at intermediate diſtances from the hair, ſo as to make fringes of intermediate colours at intermediate diſtances from the middle of the ſhadow of the hair. And in the ſecond Obſervation, where all the colours are mixed in the white light which paſſes by the hair, theſe colours are ſeparated by the various inflections of the rays, and the fringes which they make appear altogther, and the innermoſt fringes being contiguous make one broad fringe compoſed of all the colours in due order, the violet lying on the inſide of the fringe next the ſhadow, the red on the outſide fartheſt from the ſhadow, and the blue, green, and yellow, in the middle. And, in like manner, the middlemoſt fringes of all the colours lying in order, and being contiguous, make another broad fringe compoſed of all the colours; and the outmoſt fringes of all the colours lying in order, and being contiguous, make a third broad fringe compoſed of all the colours. Theſe are the three fringes of coloured light with which the ſhadows of all bodies are bordered in the ſecond Obſervation.

OBSERVATION *v*.

A PRISM being applied cloſe to a ſmall hole, one-fiftieth part of an inch wide, through which a ſlender beam of ſolar light paſſed into a darkened chamber, the beam of light was ſeparated into its various colours. Acroſs this beam of coloured light I placed variouſly, and at various angles of inclination to the direction of the axis of the priſm, the edge of a plain thin metallic body, and obſerved that the different fringes made in the differently coloured lights, were formed exactly in the ſame manner as they are formed of the ſame various lights, when the white beam is at the ſame time variouſly inflected and ſeparated into theſe lights, ſo as afterwards, by their various mixtures, to form the parti-coloured fringes before deſcribed.

The red rays therefore were bent into leſs angles of deviation towards the body from their original lines of direction,

tion, to greater diſtances, and formed into larger fringes. The purples were more bent to ſmaller diſtances, and into ſmaller fringes. The intermediate blues, greens, and yellows, were bent in intermediate angles of deviation, to intermediate diſtances, into fringes of intermediate ſizes. The dark intervals alſo between all theſe fringes of the ſame colours, were more large and more diſtinct than between the fringes of various colours. When therefore the white light, in its paſſage by the edge of any body, is at once ſeparated and bent into theſe fringes of various colours, they form by their various mixtures, at different diſtances of obſervation, the parti-coloured fringes of the foregoing obſervations to which the purples and blues are internal, being inflected to neareſt diſtances in greater angles of deviation, the reds external, being inflected to farther diſtances in ſmaller angles of deviation, and the intermediate colours to intermediate diſtances, in intermediate angles of deviation from their original direction, invading and leaving, as circumſtances may determine, dark intervals of greater or ſmaller breadths, or altogether reducing and extinguiſhing them.

In Figure κ, let ABML be a beam of white light paſsing through any tranſparent medium, as water, glaſs, or air; and let ABDC, EFHG, IKML, be portions of this white light ſeparated from each other, as they muſt be during their paſſage by the intervening parts or particles of the medium. Of this beam any portion, as EFHG, is equally attracted on all ſides by the parts and particles of the medium on every ſide ſurrounding it. For if not, it would deviate from its rectilinear direction towards that ſide where the greater attractions exiſt. If now the edge or angle X of any thin body approach EFHG, ſo as to attract it towards itſelf, EFHG is bent towards X, and ſeparated into different portions of variouſly-coloured lights, bent at different angles of deviation from the original direction of EFHG. FαβH, FγδH,

FεζH,

F$\varepsilon\zeta$H, repreſent three of the portions of coloured lights ſo formed. F$\alpha\beta$H, being the purple or neareſt colour, F$\varepsilon\zeta$H, the red or moſt remote, and F$\gamma\delta$H the intermediate blue, green, or yellow.

The changes thus produced in theſe different portions of coloured light, are various, being produced by the various actions and re-actions of the attracting edge, the particles of the medium, and the different portions of the divided light, upon and among each other. For let the different portions of divided light F$\alpha\beta$H, F$\gamma\delta$H, F$\varepsilon\zeta$H, be ſuppoſed, all things continuing the ſame, to be returned backwards in the ſame courſe through which they at firſt paſſed onwards, and it is plain that they ought to be, and will, arriving at the ſame time, at the ſame place of original ſeparation, be again bent and united into the original portion of white light EFHG. To effect this, the edge X muſt act variouſly upon each of them. The re-action of all upon X is reciprocal, and therefore muſt be various, and muſt be different in each, and from that of the whole aggregate or original portion E F H G, and therefore various changes muſt have been produced in each of theſe divided portions of light which conſtitute them different lights, as well from each other as from the original light.

Theſe different changes, or the conſtitutions or modifications of theſe different portions of ſeparated light muſt alſo be permanent, and muſt continue in them through all their future progreſs; for if not, they would not, as they always muſt, poſſeſs them when returned back without any change of circumſtances to their original point of ſeparation.

Not only are theſe changes or modifications various and permanent, but each of theſe ſeparated portions of coloured light is, throughout all its ſubſequent paſſage, amidſt the particles of the ſame medium, equally attracted by, and attracting, acting, and acted upon by the parts and particles of the ſurrounding medium. For this is neceſſary to its continued ſtate of rectilinear propagation. It is indifferent therefore as to all its future actions and re-actions upon and between X, on which ſide X approaches, provided all other circumſtances of the approach be the ſame, and whether it is approached and acted upon by X, or by any other body capable of acting upon it.

Each of the other portions of light, A B D C, I K M L, is affected and changed in the ſame manner as the portion E F H G, and theſe taken altogether, are the portions of white light, which being variouſly bent, ſeparated, and changed into the various portions of differently coloured lights, form all the fringes and intervals of the preceding Obſervations.

It is plain therefore from the circumſtances of this, and of all the foregoing Obſervations, that the phænomena of the Inflections of Light are the conſequences of the various bendings, ſeparations, and changes produced in each of the ſeparate portions of a beam of white light paſsing between the parts and particles of a tranſparent medium, by the action or attraction of the edge, angle, or ſide of an approaching body; each of theſe portions being variouſly bent and ſeparated into other portions of differently-coloured lights, each of which being changed from and receiving a conſtitution or modification different from that of all the others, and from that of the original portion out of which it was derived, retains that conſtitution or modification permanently, until it be again re-united into the ſame, or a ſimilar portion of white light, among the properties of which conſtitution or modification it is one; that paſsing at the ſame diſtance with rays of other colours from and by the edge of an inflecting body, it is conſtantly bent at angles of deviation different from thoſe of all other colours; the purples moſt; the blues leſs than the purples; the yellows, greens, and reds, ſucceſsively leſs and leſs, ac-

cord-

cording to the order of their ſpecification.

Such a ſtate and condition, and ſuch changes of light, are abſolutely neceſſary for the exiſtence and regular formation, under different circumſtances, of the fringes ; they are conformable to the general nature and principles of things, and being required, are eſtabliſhed by the phænomena, and being eſtabliſhed by, explain them.

That a beam of white light is compoſed of rays of different ſorts, originally and always diſtinct, and of various colours, which are only ſeparated from one another, is an hypotheſis inconſiſtent with all the phænomena of inflections.

Indeed the very circumſtance of the diſtribution of white light into colours, which admit of degrees and not of diviſions, and the difficulty of conceiving in what manner, whether of particular arrangement, or undiſtinguiſhed mixture, they muſt be re-united to form white, without conceiving or ſuſpecting that differences might, and it would ſeem, ought to ariſe of colours from various orders or modes of combination, would lead us to infer, the action of *a principle*, which *changes* and *modifies* at the ſame time that it *ſeparates* every portion of the white light, and requires an actual reſtoration of all things to the ſame original, or exactly ſimilar circumſtances of condition for its re-production.

Let A B Z Y, in *Fig.* λ, be a beam of white light compoſed of the various coloured rays A B D C, E F H G, I K M L, N O Q P, R S U T, V W Z Y, paſsing between the parts and particles of a tranſparent medium, and let the rays A B D C, E F H G, I K M L, be purple, yellow, and red, according to the order of their nomination; and alſo N O Q P, R S U T, V W Z Y, purple, yellow, and red, and let the edge or angle of a body at X act upon them variouſly, and inflect them in manner and according to the principles eſtabliſhed by the foregoing Obſervations. They will, under theſe circumſtances, form one of the coloured fringes of theſe Obſervations. But it is only under the particular circumſtances of this poſition of the body, and this arrangement of the rays that they will form ſuch fringes. If X be conceived to be between D, and F, the internal purple of the firſt fringe will be taken away, and the yellow appear in its ſtead. Nor can its place be ſupplied by the next neareſt purple N O Q P, without ſuppoſing that purple to be more bent in order thereto, though more remote than the nearer purple which has been excluded. If the body be removed altogether to the oppoſite ſide, the arrangement of the rays will be altogether different from that which is required. If the body be moved in circuit round the central point between M and O, at every point of its progreſs, a new and an appropriate arrangement of the rays will be required. Thus at one and the ſame time, in the ſame place, the ſame and a different order and condition of things is required, which is impoſsible.

If the rays be ſuppoſed to be confuſedly mixed in the white light, no regular formation of the fringes can be expected to be produced from amidſt ſuch diſorder; nor will theſe difficulties be removed by conceiving every beam of white light to be again diviſible into ſmaller portions or beams of white light compoſed of all the various colours, ſince even in theſe again, a peculiar arrangement is required, which yet ſhall, as different occaſions demand, differ from itſelf, and without a given appropriate arrangement, there can be no regular formation, according to the before eſtabliſhed principles of exiſtence of the fringes.

The fringes require that complete ſets of the different coloured rays ſhould iſſue *at the ſame time* from *each* interſtice or point of paſſage of the medium, each of which rays ſhould be equally related as to diſtance from the inflecting body on one ſide, and the particles of the medium on the other, at the time of diſtribution or ſeparation, and equally related each afterwards as to diſtance and attraction to all the particles of the medium on all ſides, and capable of being returned again, and of being united *at the ſame time in the ſame place*, under the ſame relations, circumſtances altogether inconſiſtent with the nature of, and impoſsible with originally and perpetually different, diſtinct, and ſeparate rays.

The portions of light which paſs through the intervals between the particles of bodies, are truly and properly the rays of light.

Thus it is firmly eſtabliſhed, that in the inflections of light, each white ray of paſsing light is ſeparated into many diſtinct rays; that of theſe rays, at the time of ſeparation, each ſuſtains a change; that this change conſtitutes a difference of each ray from every other, and from the original white ray; that this change or modification is permanent in each ray throughout all its future courſe of ſeparate propagation; that this change or modification in each diſtinct ray, operates during all the future propagation of the ray, its different and appropriate effects; that this change or modification produces in each ray, under the ſame circumſtances, unequal, and under different circumſtances, equal changes of direction of courſe.

All this will further more clearly appear when the true nature of light itſelf is underſtood, and the principles of production of theſe changes explained. Upon theſe changes, their effects and conſequences, depend the exiſtence and production of colours.

Although, however, no collateral arrangement of ſeparate rays will apply to theſe phænomena, yet indeed if all the different ſorts of rays be ſuppoſed to follow each other through the ſame paſſages in rapid ſucceſsion, at intervals of time not diſtinguiſhable by ſenſe, then, as wherever there are ſeparations, there are alſo modifications; and as permanent modifications, after ſeparation, actually conſtitute afterwards different, and differently coloured rays, the doctrines of ſimple ſeparation, or of ſeparation and permanent modification, will equally apply to all caſes of colours; and whatever one will explain, the other will alſo. Thus matched, the eſtabliſhment of either muſt be determined by other phænomena, and by general principles.

But the doctrine of original diſtinctneſs of exiſtence and ſubſequent ſimple ſeparation of the rays, is inconſiſtent with all the general phænomena of light and of nature. It is impoſsible by it to underſtand or explain theſe, or the relations that exiſt between theſe. The Newtonian doctrine, therefore, explains not the general phænomena of light, but only enquires if light be not emitted, reflected, refracted, inflected, and, it might have been added, *coloured* by one and the ſame principle. But the doctrine of modification, equally applicable to the phænomena of colour, is conſiſtent with, and eſtabliſhed by the general conſent of all the phænomena.

The Newtonian doctrine of light and colours depends upon two principles; the fits of eaſy tranſmiſsion and reflection, and the original differences or ſorts of the rays. By thoſe the phænomena of rings of colours, by both, the reflections, refractions, and colours, produced by thick tranſparent bodies, have been explained.

The fits of eaſy tranſmiſsion and reflection are only particular caſes of inflections.

The deviations of courſe, and ſeparations into colours of the rays in the refractions of light, at the ſurfaces of incidence of thick tranſparent bodies, are mere circumſtances of inflection.

The diviſion of the incident beams of light in theſe caſes, into two beams, one of which is reflected, and the other refracted, depends upon principles of which the accepted philoſophy of the day has no idea.

Newton concludes his Obſervations concerning the Inflections of Light with the following words:

> When I made the foregoing Obſervations, I deſigned to repeat moſt of them with more care and exactneſs, and to make ſome new ones for determining the manner how the rays of light are bent in their paſſage by bodies, for making the fringes of colours with the dark lines between them. But I was then interrupted, and cannot now thing of taking theſe things into farther conſideration. And ſince I have not finiſhed this part of my deſign, I ſhall coneude with propoſing only ſome Queries in order to a farther ſearch to be made by others.

With what conſequences this farther ſearch has been made, the Obſervations which accompany theſe ſhew; and they ſupply alſo anſwers to the three firſt queries of Newton.

I have corrected all the Newtonian Obſervations concerning the Inflections of light:

I have made Obſervations concerning the Inflections of Light, which hitherto had eſcaped the attention of all who have conſidered theſe phænomena:

I have explained the manner in which the rays of light are bent and diſtributed to produce theſe appearances:

I have ſhewn that the doctrine of modification and ſeparation in all caſes ſufficient, is equally applicable with that of ſimple ſeparation of the rays of light to the phænomena of colours in that ſingle caſe of arrangement of the ſuppoſedly diſtinct rays which alone can conſiſt with the appearances:

And thus I have prepared the way for a more eaſy and natural ſolution of the phænomena of light, than by the hypotheſes of *fits* and *ſpecies* of the rays. Theſe hypotheſes, if I err not, are inconſiſtent with the actual condition of things, and the general phænomena of light and of nature. They have not been, for they cannot be, applied to explain them; they obſtruct all diſcovery concerning them; they interrupt the general progreſs of philoſophy.

I ought now, in a due courſe of progreſs, to proceed to the ſecond, and afterwards to the firſt books of theſe Optics, the neceſſary amendments of which are even more numerous and more important than theſe of this third book. This I propoſe to do, and the work is in a conſiderable ſtate of advancement. But the completion muſt be deferred, and may never be effected. For this reaſon

alone

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alone I have here added theſe laſt concluding Obſervations which anticipate thoſe objects.

The reformation of theſe parts of the Newtonian philoſophy, which for more than a century have ſtood unqueſtioned, and been ſo long conſidered as eſtabliſhed beyond all reach or power of queſtion, is of infinite importance and incalculable value to general philoſophy. The phænomena of light, connected obviouſly with thoſe of heat and of electricity, which have ſo much engaged the attention and inveſtigation of the preſent day, are really connected with all the phænomena of the univerſe. Without this reformation, it is abſolutely impoſsible for philoſophy to make further progreſs.

The reformation of this, and of other ſyſtems in other departments of philoſophy, forms, however, only an inconſiderable and ſecondary part of what may be done. The moſt extenſive and important diſcoveries muſt precede and lead on to theſe conſequences.

I ought, from the reformation of the Newtonian doctrine of light and colours contained in theſe three books of his Optics, to go on afterwards to explain the manner in which of light the exhibition, emiſsion, propagation, extinction, inflection, reflection, refraction, colorification, and all the phænomena are truly and actually effected; for indeed I conceive that I have diſcovered the principles of exiſtence of all the phænomena of light; and not of light alone, but alſo of heat and of electricity, and the relations which exiſt between theſe.

Theſe diſcoveries cannot exiſt without a conſiderable number of others connected with, and dependant upon theſe; and are followed by an immenſe train of conſequences and deductions. From them the moſt wonderful diſcoveries ſeem to reſult reſpecting the conſtitution of the univerſe, and the connections of its parts, the connections of the particles of bodies, and of the bodies themſelves. By them we ſeem to be led to judge of all thoſe appearances which the air, the earth, the heavens exhibit, to know of the conditions of bodies, their fixity, fluidity, elaſticity; to diſcover and diſtinguiſh the operations of heat, light, and the general agents of nature, from thoſe of the bodies with which they are blended in mixture and in action, to underſtand the effects of attrition, colliſion, combination, and all thoſe natural phænomena about which the preſent philoſophy enquires and doubts, and has hitherto only enquired and doubted.

By light alone can we have acceſs to the groſſer bodies of nature around us, whoſe arrangements and motions Pythagoras and Copernicus obſerved, and Newton demonſtrated. By light and heat alone can we have acceſs to the interior parts of natural bodies, preſerving their union ſo as to judge of their formation; or, ſeparating them, to determine the parts of which they are compoſed. When of light upon the organs of ſenſe, the actions hitherto attributed to impulſe, which exiſts not, ſhall be underſtood, information may be hoped for reſpecting the principles, whether of ſtructure of parts, or combination of ſubſtance, or both, upon which animal ſenſations and motions depend.

The phænomena of light, heat, electricity, magnetiſm, and gravitation, have always been, as they only can be, referred to modifications of the particles of bodies, or to exiſtences, for which the only place in nature is in the pores of, and between the bodies themſelves. Thus connected by ſimilarity of cauſe or ſameneſs of place, the knowledge of the principles of exiſtence of any one ſet of theſe, neceſſarily, almoſt, involves the knowledge of others. The actual diſcovery therefore of the cauſes and relations of the phænomena of light, heat, and electricity, leads immediately to thoſe of magnetiſm, not however to be divined and deduced by argument, but to be diſcovered and eſtabliſhed by experiment.

In the phænomena of gravitation, whilſt the tangential motion of a planet can only be referred to the paſt unknown hiſtory of the motions of the univerſe for its exiſtence, the centripetal motion is produced by cauſes actually preſent. Whilſt we contemplate the body, it receives a motion which it had not before, and by which it is diverted from its rectilinear courſe. Of the motion thus imparted, it is the buſineſs of philoſophy to find out the cauſe. A knowledge of the direction or point to which any of theſe motions tend, may aſsiſt to guide us to, but their cauſe can only depend upon the condition of things around. To a knowledge of this condition, theſe diſcoveries promiſe to lead.

The condition of things thus eſtabliſhed by the beſt evidence, can alone furniſh

the

the means of explanation of all the circumſtances of exiſtence, change, and appearance of this earth whoſe ſurface we inhabit, of the ſecondary that attends us, of the opaque planets and reſplendent comets, of the ſun, to whom our motions are referred, and of thoſe other everlaſting fires which ſhine around us;—a condition, how different from that, which, to the contemplative eye, repreſents only in the void immenſe, globe to move round globe, or remaining, detached each from the others at immeaſurable diſtances in boundleſs ſpace, without connection, relation, or dependance.

Many years have paſſed away ſince the diſcoveries, thus important in themſelves, and in their conſequences, have been accompliſhed. Buſied in the cares of life, of profeſsional occupation and domeſtic eſtabliſhment, little of what is neceſſary has been done either to preſerve or tranſmit them to other perſons and times. I could not reſtrain the march of my mind in inveſtigation, but for the leſs ardent work of literary compoſition the occaſions were not granted ; and of all that may have been done, few and inconſiderable are the written ſtatements. Their exiſtence, therefore, depends upon mine, and with me they may periſh. They lie upon my mind as would the diſcoveries of paſt ages, if at this moment all the books ſhould diſappear, in which they are contained, and they require, as would thoſe, much labour, conſiderable time, and diſengaged attention to give them the completion of matter, arrangement and form neceſſary to their perfect preſervation.

All that I can, I will endeavour to effect.—But I muſt return to thoſe cares, to labours which afford but little of vacancy for other purſuits. I muſt perform, as becomes me, the duties which are mine of natural relation, and which are paramount to all others. I fear, I regret, not for myſelf alone, that little can be that all which may be expected under ſuch circumſtances. I may, however, only regret a ſtate of things which I can neither controul nor change.

I ſpeak with diffidence of all theſe things. Againſt ſelf-deception, after the examples exhibited in theſe Obſervations, who can be ſecure? Upon the faith, however, of theſe ſame Obſervations, ſome expectation may be formed, and ſome credit claimed.

London, May 1,
1799.

G. W. J.

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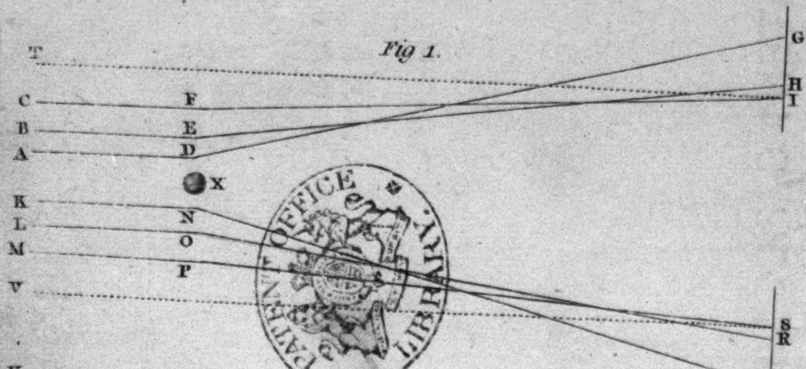

Fig 1.

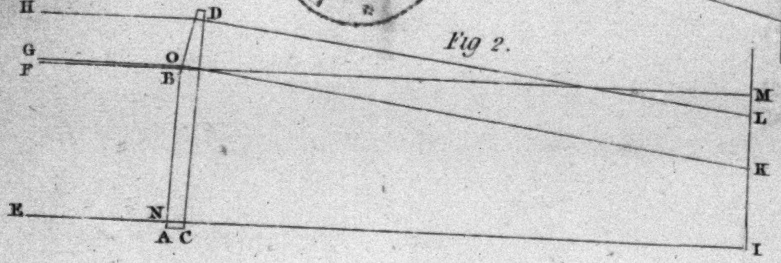

Fig 2.

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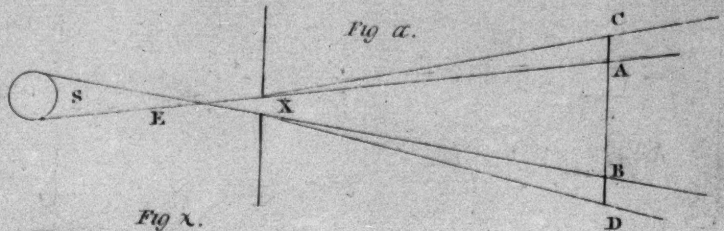

Fig α.

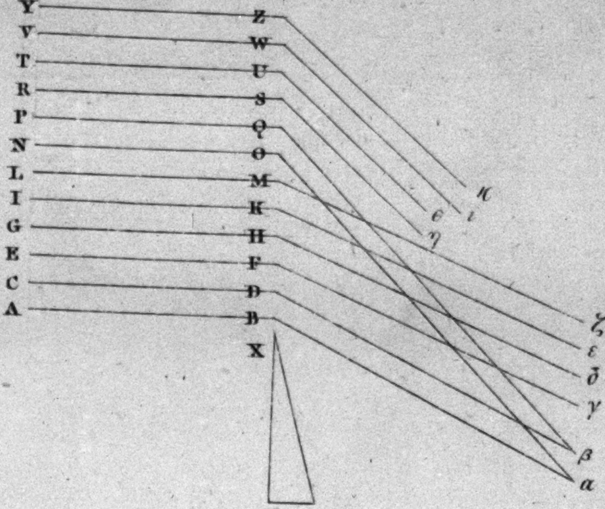

Fig λ.

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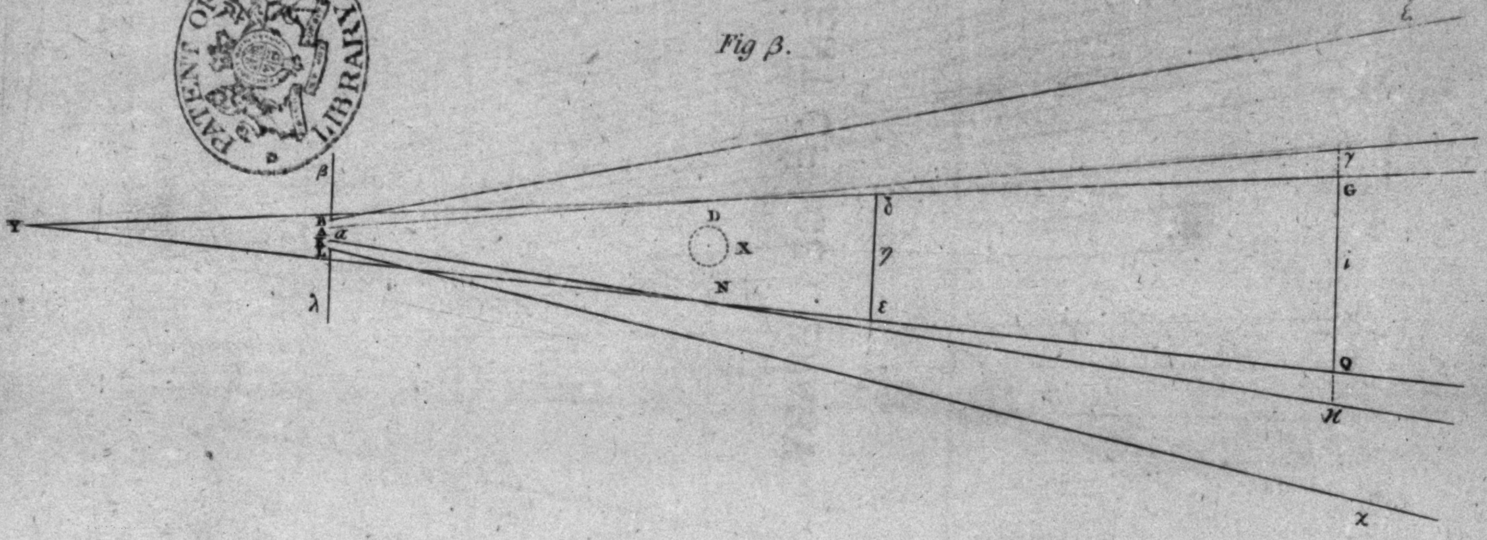

Fig β.

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Fig 7.

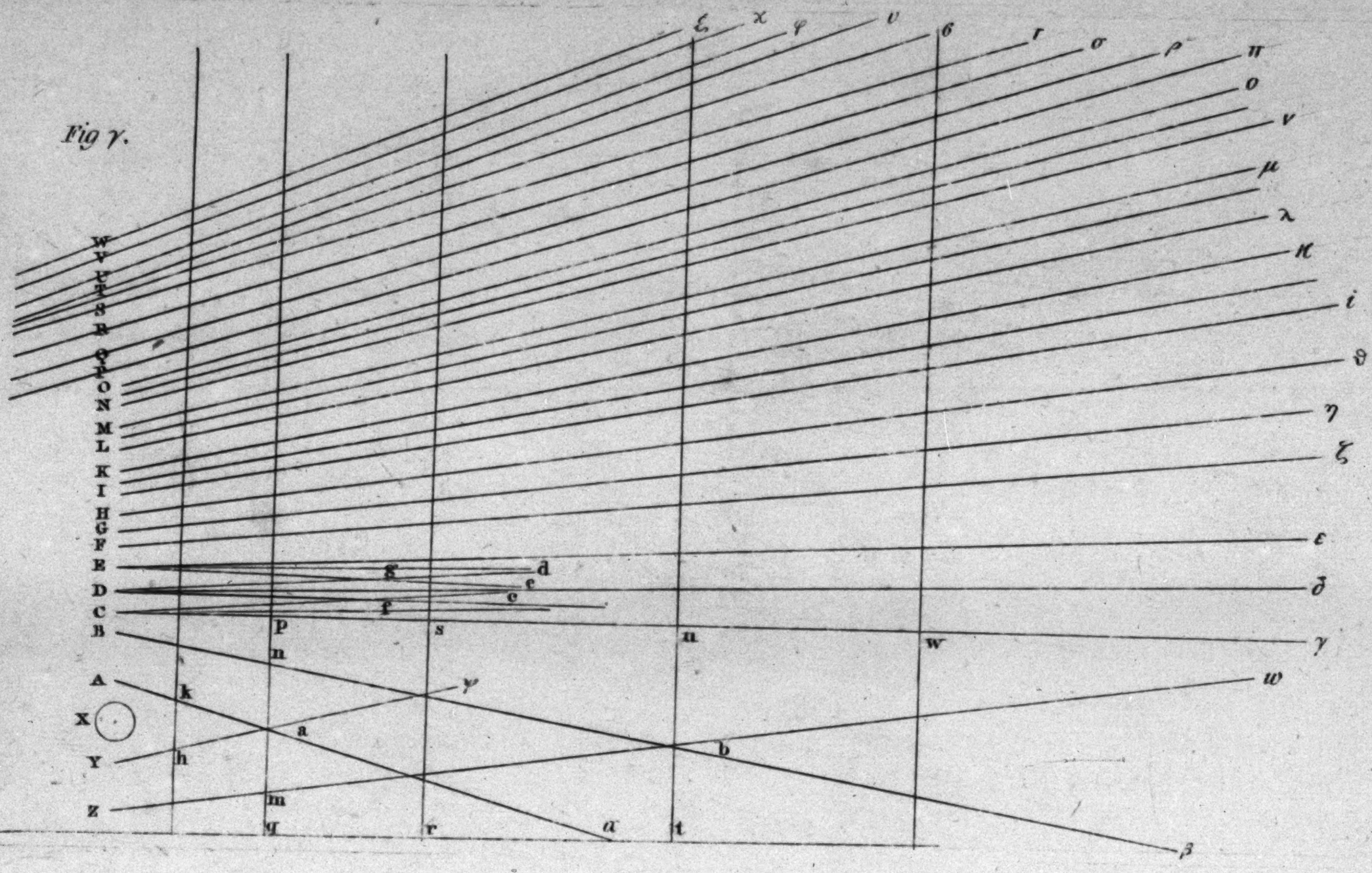
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Fig ε.

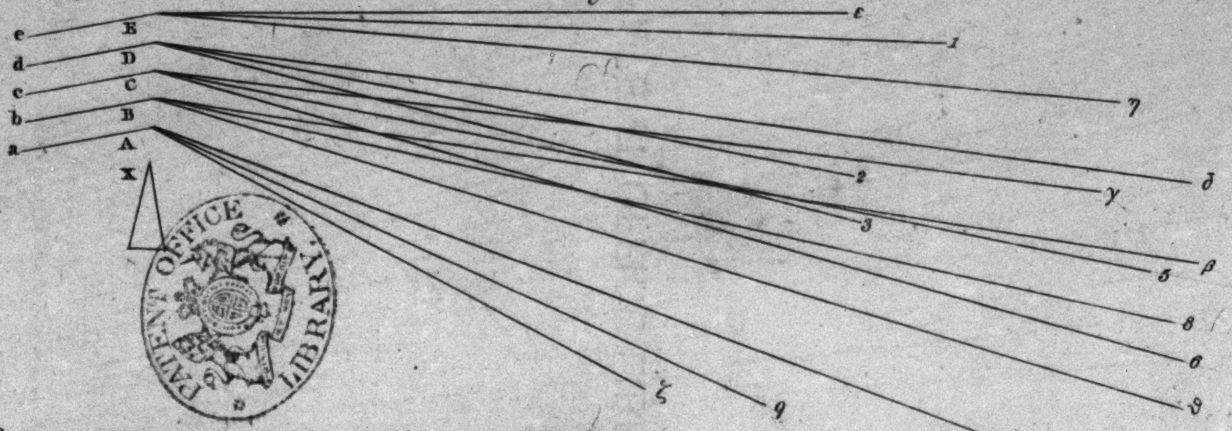

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Fig δ.

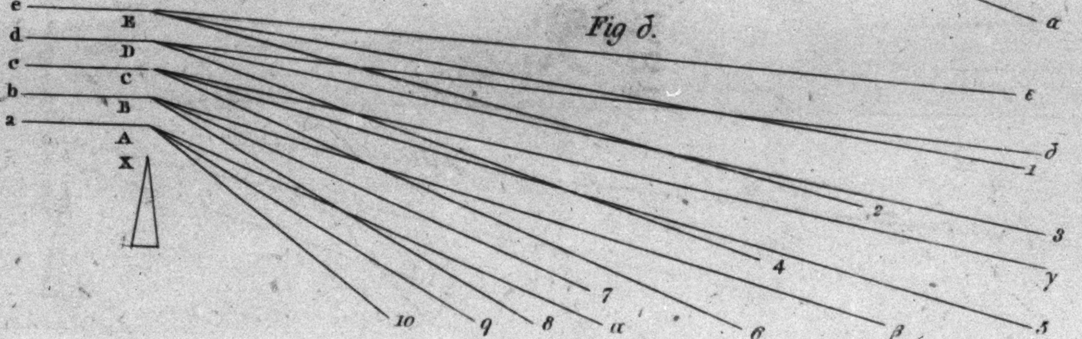

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Fig ζ

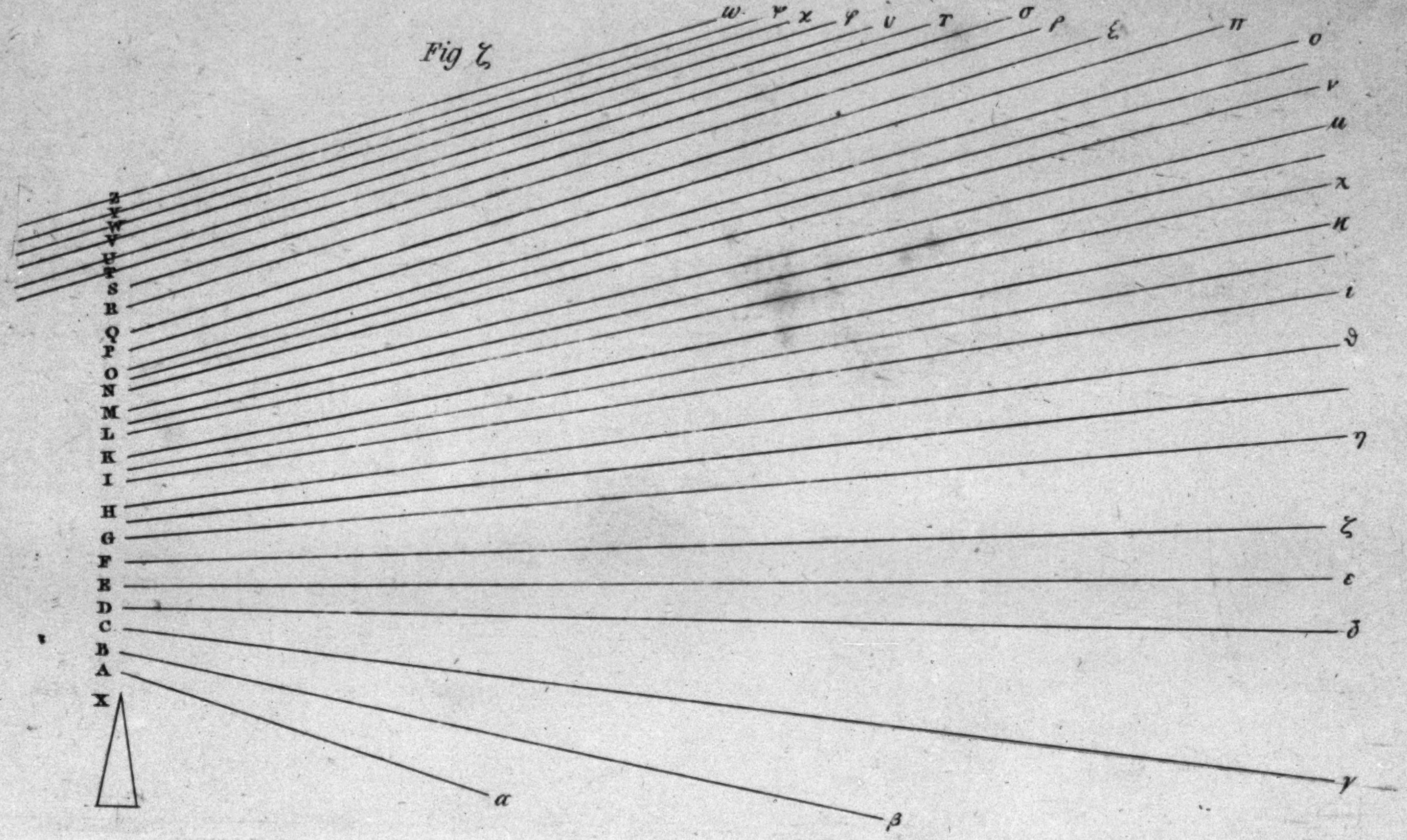

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Fig 7.

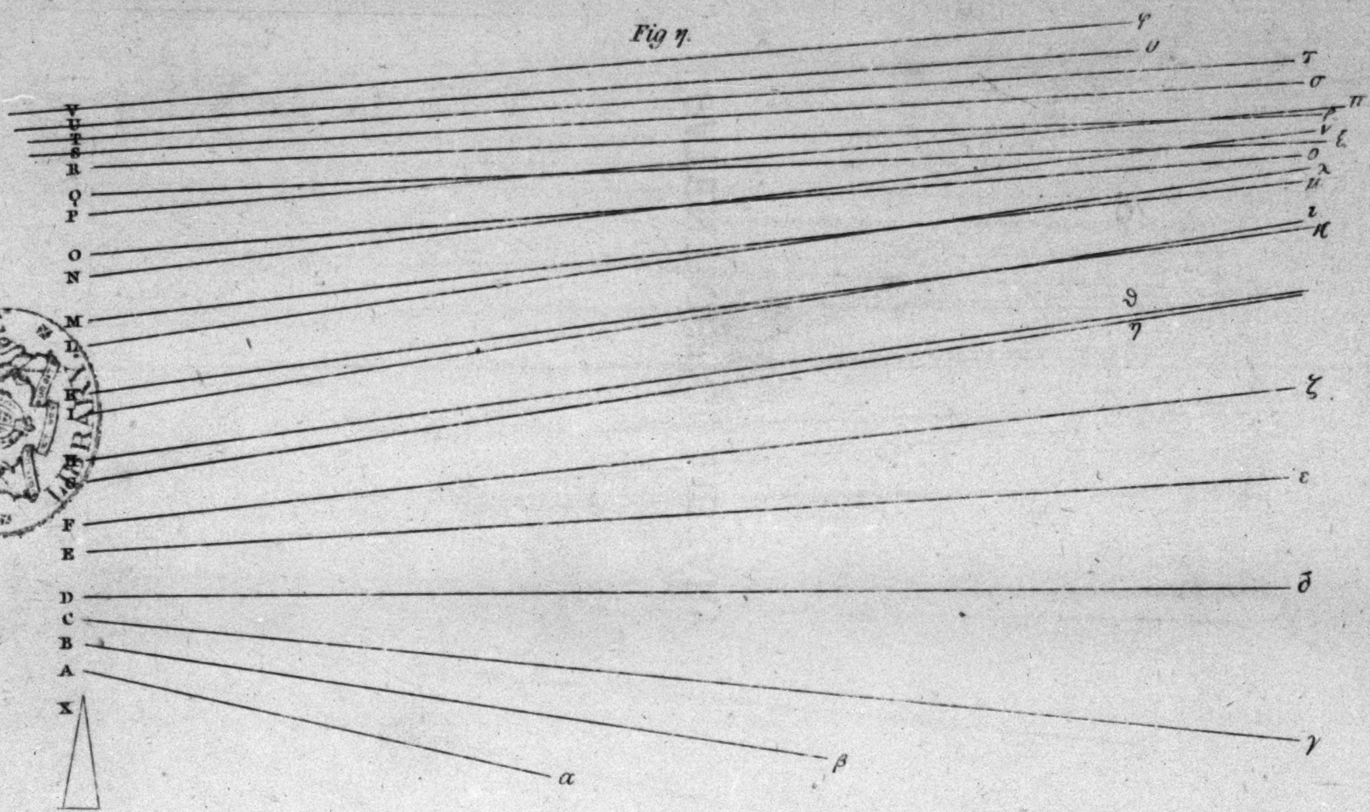

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Fig. 3.

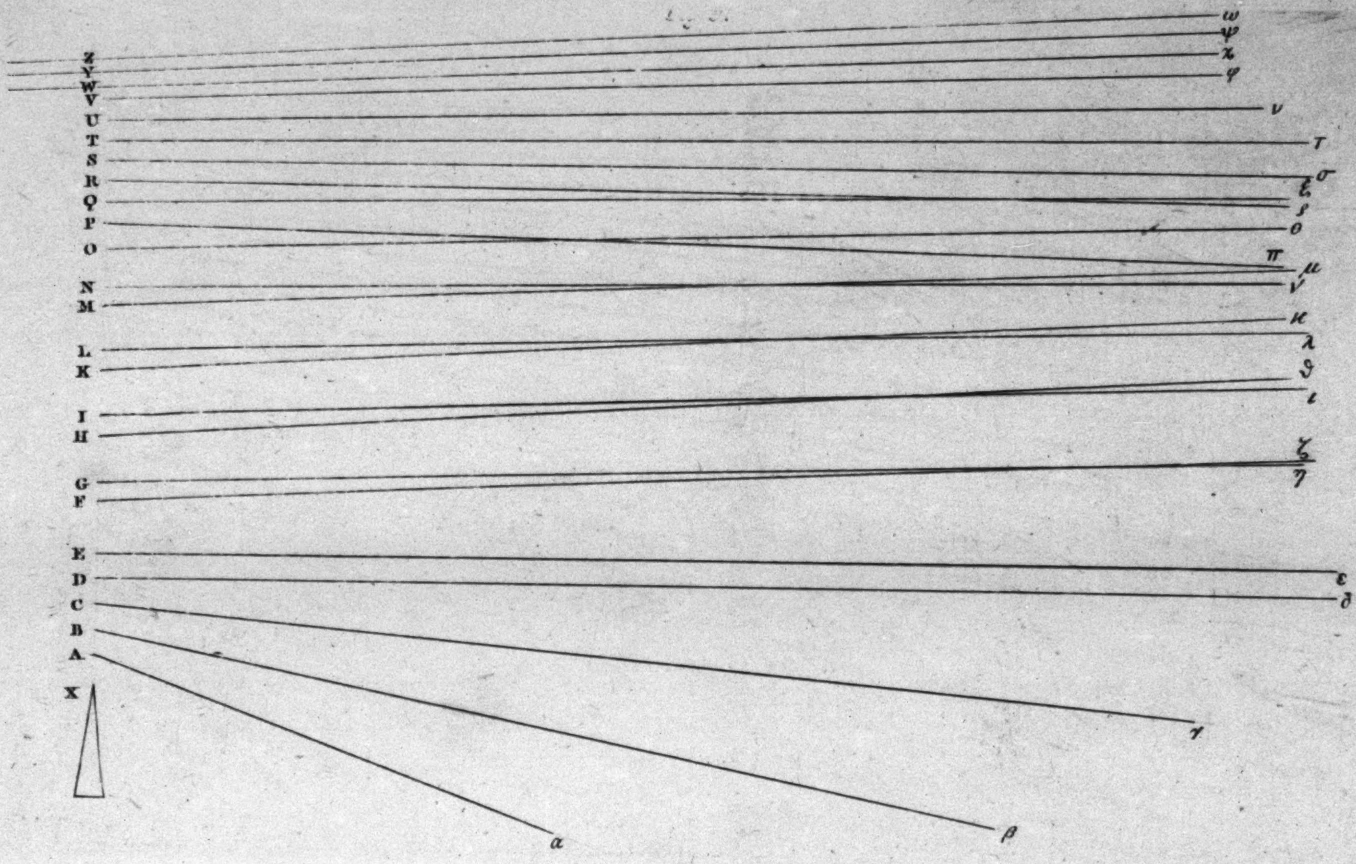

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Fig 1.

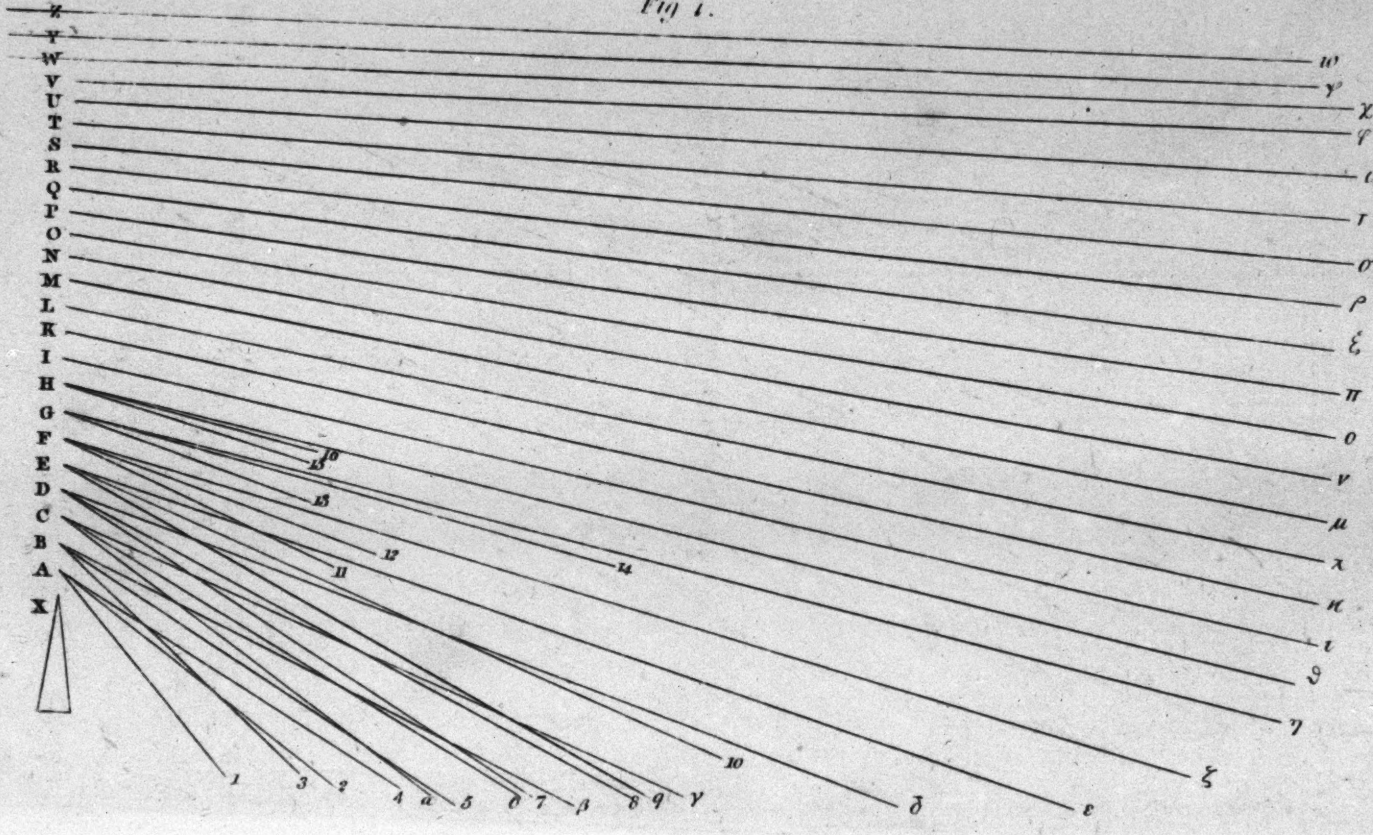
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Fig 3.

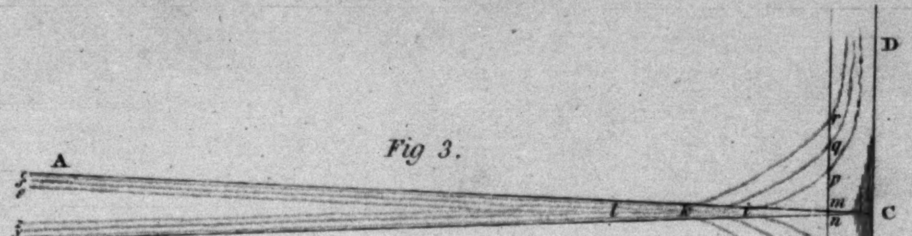
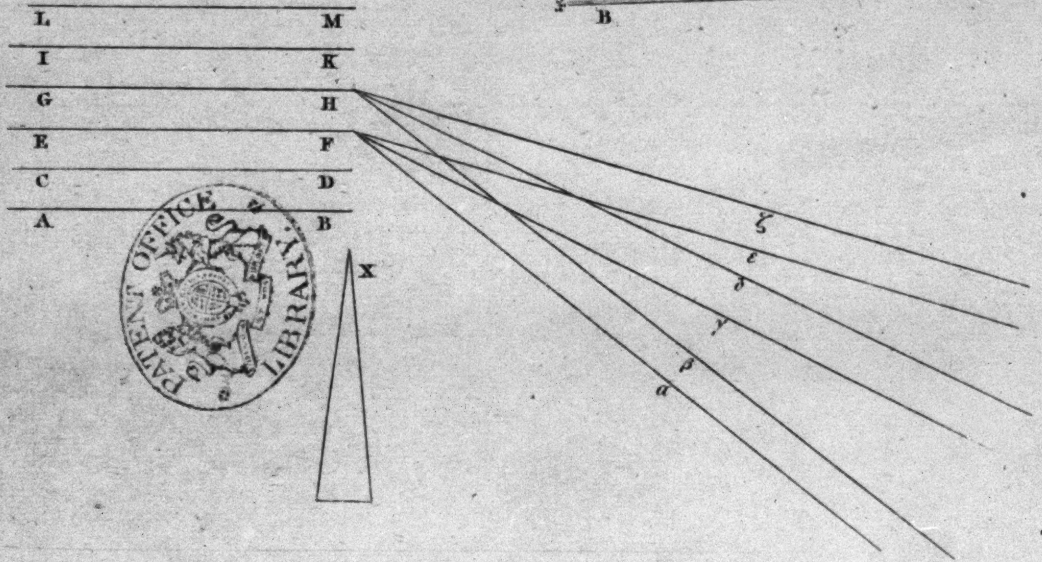


Fig 11.



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